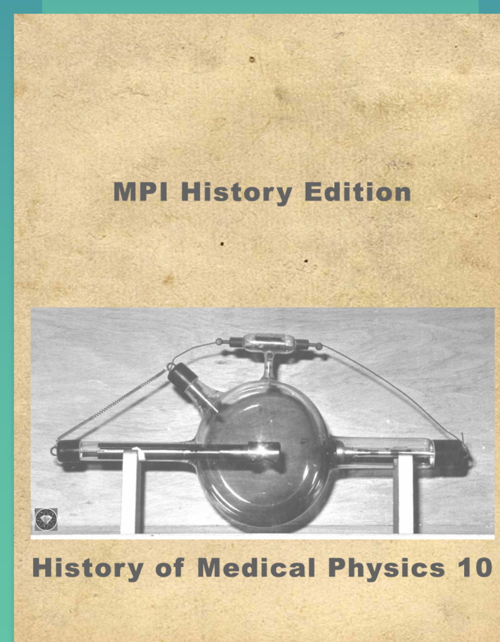
MEDICAL PHYSICS
International



IOMP

The Journal of the International Organization for Medical Physics

History Edition 10, June 2024

MPI

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THE JOURNAL OF

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MEDICAL PHYSICS INTERNATIONAL
The Journal of the International Organization for Medical Physics

Aims and Coverage:
Medical Physics International (MPI) is the official IOMP journal. It provides a platform for medical physicists to share their experience, ideas and new information generated from their work of scientific, educational and professional nature. The e-journal is available free of charge to IOMP members. MPI- History Edition is dedicated to History of Medical Physics.

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EDITORIAL

Slavik Tabakov, Perry Sprawls and Geoffrey Ibbott
MPI Special Issues Co-Editors

This 10th issue of the IOMP Journal Medical Physics International – History Editions (MPI-HE), focusses on the 60th Anniversary of the International Conferences on Medical Physics (ICMP) from their beginning in 1965. It includes one article describing the history of the ICMPs 1965-2025 and two large Annexes, including the Book with Abstracts of ICMP 1 (Harrogate, UK, 1965) and another Book with papers from the First International Conference on Medical Physics Education (Budapest, 1994). These Annexes present a very clear picture about the progress of the medical physics science in the past 60 years, and the progress of medical physics education in the past 30 years. The MPI-HE issue also includes papers about Medical Physics Virtual Exhibits, X-ray Mania Advertising from 1895; The Evolution of Visibility of X-ray Medical Imaging.

We are very happy to see that the overall popularity of the History Project is continuing and each MPI - History Edition has thousands of downloads. All of the medical physics history articles can be accessed through:
http://www.mpijournal.org/history.aspx

The History topics extensively covered in MPI-HE so far include:

MPI-HE 1- http://www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01.pdf

MPI-HE 2 - http://www.mpijournal.org/pdf/2019-SI-02/MPI-2019-SI-02.pdf

MPI-HE 3 - http://www.mpijournal.org/pdf/2020-SI-03/MPI-2020-SI-03.pdf

MPI-HE 4 - http://www.mpijournal.org/pdf/2020-SI-04/MPI-2020-SI-04.pdf

MPI-HE 5 - http://www.mpijournal.org/pdf/2021-SI-05/MPI-2021-SI-05.pdf

MPI-HE 6 - http://www.mpijournal.org/pdf/2021-SI-06/MPI-2021-SI-06.pdf

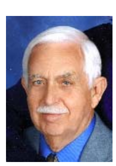
MPI-HE 7 - http://www.mpijournal.org/pdf/2022-SI-07/MPI-2022-SI-07.pdf (with papers on history of IOMP)

MPI-HE 8 - http://www.mpijournal.org/pdf/2022-SI-08/MPI-2022-SI-08.pdf

MPI-HE 9 - http://www.mpijournal.org/pdf/2023-HE-09/MPI-2022-HE-09.pdf

Additionally, history information about the development of medical physics in all continents can be seen in the Regular issues of MPI 2019-2021, where all IOMP Regional Organisations included papers about the professional and educational development in many of the countries within their geographical areas. The content of the IOMP Journal MPI – History Edition supports the objective of the History project: to research, organize, preserve, and publish on the evolution and developments of medical physics and clinical applications that are the foundations of our profession. We welcome contributions of colleagues from all societies, organizations and companies who would like to join the History project with articles on specific topics. We look forward to receiving your suggestions.


Prof. Slavik Tabakov


Prof. Perry Sprawls


Prof. Geoffrey Ibbott

15 YEARS IOMP HISTORY SUB-COMMITTEE

Slavik Tabakov[1,2,3]

[1] King's College London, UK, [2] Past President IOMP, [3]Chair IOMP History Sub-Com

The IOMP History Sub-Committee (HSC) was established during the IOMP office 2006-209. It was an activity led by the IOMP Past-President A Niroomand-Rad, who became the first Chair of HSC in 2008. The HSC is not part of ExCom, as a Sub-Com it is placed under the IOMP Publication Committee. Its charge is to keep information about IOMP history, its active members and related data.

The members of the HSC so far include:
2008-2012 Azam Niroomand-Rad, Chair (USA)
Colin Orton (USA)
Slavik Tabakov (UK)
Robert Gould (USA)
2012-2015 Azam Niroomand-Rad, Chair (USA)
Colin Orton (USA)
Peter Smith (UK)
KY Cheung (Ex-Officio)
2015-2018 KY Cheung, Chair (Hong Kong, PR China)
Colin Orton (USA)
Peter Smith (UK)
Slavik Tabakov (Ex-Officio)
2018-2022 Slavik Tabakov, Chair (UK)
KY Cheung (Hong Kong, PR China)
Colin Orton (USA)
Madan Rehani (Ex-Officio)
John Damilakis (Ex-Officio)
Paolo Russo (Ex-Officio)
2022-2025 Slavik Tabakov, Chair (UK)
Azam Niroomand-Rad, USA
Geoffrey Ibbott, USA
KY Cheung, Hong Kong
Perry Sprawls, USA
John Damilakis, Greece (Ex-Officio)
Eva Bezak, Australia (Ex-Officio)
Francis Hasford, Ghana (Ex-Officio)

The first activities of HSC were at the WC2009 in Munich when a number of past IOMP Presidents, Chairs and active members were interviewed. The videos of these interviews were arranged by S Tabakov and M Stoeva as a free-access web activity. These interviews are now being re-established.

During the period 2010-2015 HSC collected information and published the full History Tables of the IOMP, listing various activities and each individual member of each Committee from the establishment of IOMP in 1963. These were published at the IOMP web site and are updated by HSC during by each IOMP term of office.

During 2017 a long-term project was initiated "History of Medical Physics", which initially began its publications as Special Issues of the IOMP Journal Medical Physics International. The first issue related to the history of the profession was published in 2018 with Founding Editors Slavik Tabakov and Perry Sprawls. In 2019 Geoff Ibbott join the Editorial team and the three Co-Editors in Chief continue to produce 1 or 2 history-related issue each year. In 2022 the history editions were separated as an independent part of the MPI Journal family – MPI History Editions.

In the period 2019-2022 the MPI regular issues included topical papers tracing the professional development within each of the IOMP Regional Organisations (Federations). In 2023 the MPI History Editions (MPI-HE) issue was dedicated to the women-pioneers in medical physics.

In June 2022 MPI-HE published a full issue dedicated to the 60th Anniversary of IOMP, including as an Annex all 35 IOMP History Tables (with lots of information and all IOMP Committee members – over 1000 during these 60 years). This issue (230 pages) has thousands of downloads.

HSC express special gratitude to all its members and to the MPI-HE contributors over these 15 years. We encourage authors to contribute to the IOMP history-related activities for keeping a good track of the development of the profession and its contributions to contemporary medicine.

Specific history-related links and issues:

1. IOMP History Tables: https://www.iomp.org/history-sub-committee-activities/
2. History of Medical Physics – project description: http://www.mpijournal.org/pdf/2017-01/MPI-2017-01-p068.pdf
3. MPI-History Edition listing the history of the IOMP and all 35 History Tables: http://www.mpijournal.org/pdf/2022-SI-07/MPI-2022-SI-07.pdf
4. MPI-HE web address with all history issues: http://www.mpijournal.org/history.aspx

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THE VALUE AND OPPORTUNITIES OF VIRTUAL EXHIBITS For *PRESERVING AND* EXPLORING *THE HISTORY OF MEDICAL PHYSICS*

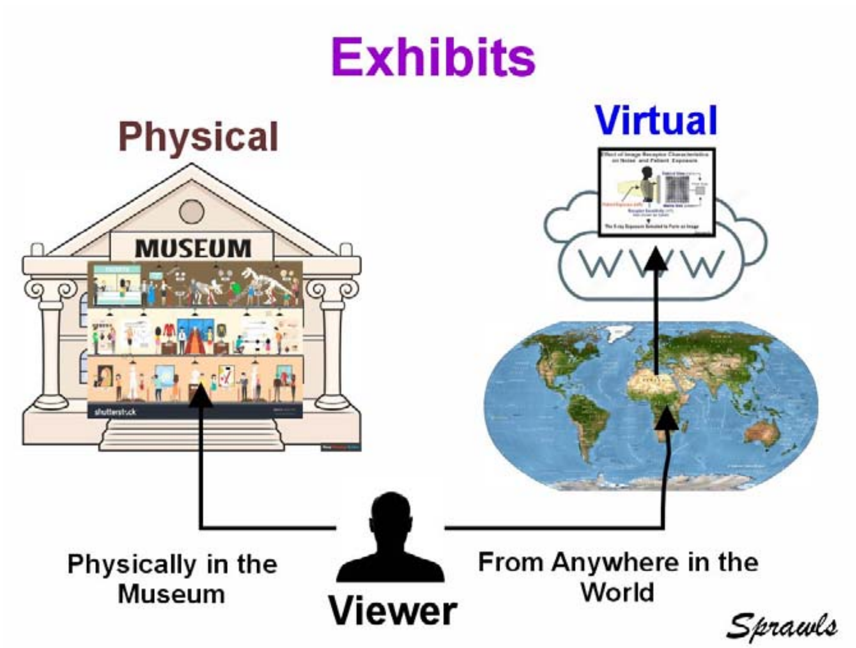
P. Sprawls[1]

[1] Emory University Radiology and Imaging Sciences, Atlanta, USA
Sprawls Educational Foundation, www.sprawls.org

I. INTRODUCTION

Exhibits, as considered here, are displays created and designed to provide an observer/viewer with a learning experience about specific objects(artifacts), artistic creations, or events, that are of historical significance. They can be either *physical* or *virtual.* Both types have their distinct values, but also their limitations.

A great value of *exhibits*, compared to other resources, such as printed publications, for exploring history, is that they provide for *physically viewing* items and activities of the past in a guided learning experience. Vision is the most significant of the human senses for developing a comprehensive knowledge of physical items and activities, especially when it is augmented with additional information as will be described below.



Physical Exhibits

Physical exhibits are generally displayed in museums or at conferences where people can view and perhaps physically interact with them. The *great value* of physical exhibits is the ability to directly observe and interact with and feel connected to the objects or topics of the exhibit. A *major limitation* of physical exhibits is they are only available to people who are physically present and looking directly at the exhibit.

Virtual Exhibits

Virtual Exhibits are *digital representations* (usually images along with descriptions) of items of the physical universe including instruments, equipment, systems, procedures, projects, and events that are made available on the internet/WWW.

The *immense value* of virtual exhibits is their availability on the internet/web as an open resource for all to connect with and learn about from anywhere in the world. Virtual exhibits relating to medical physics are now posted by both physical and virtual museums along with a variety of educational institutions and organizations.

The *creation of virtual exhibits* provides an opportunity for individual medical physicists to become “archivists and historians” and use their experiences, memories, and collections of items (artifacts), to contribute to, and receive recognition for the preservation and presentation/publication of our rich history and heritage.

The objective of this article is to encourage medical physicists to create exhibits by providing examples and links to existing virtual exhibits, comparing virtual and physical exhibits, and describing the characteristics and design of exhibits that can provide effective learning experiences.

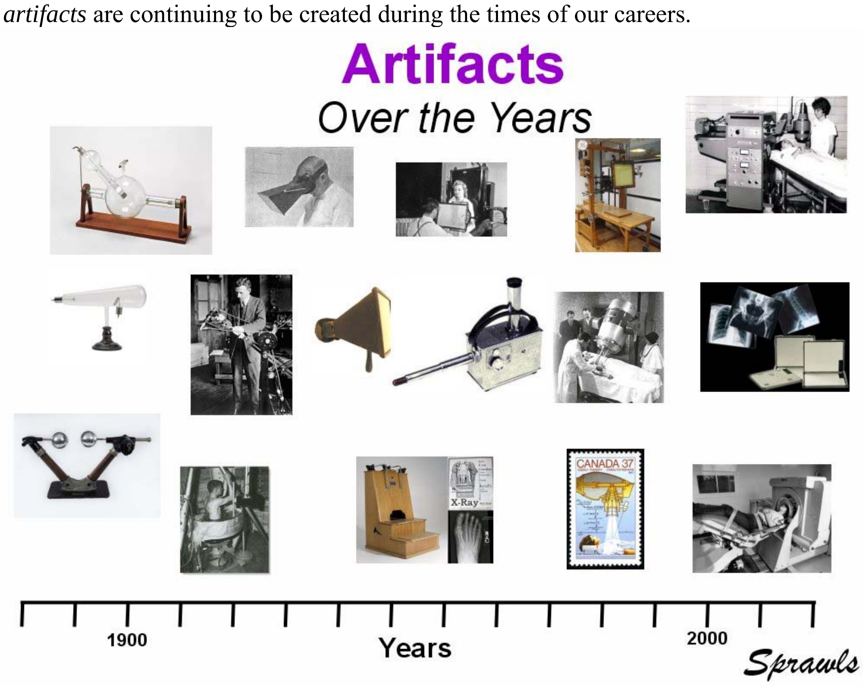
II. Collecting and preserving artifacts

An *artifact*, as considered here, is an object or item created and used by humans in the past that has potential historical value in helping to understand the activities of previous generations. They are distinctly different from *specimens* of naturally occurring objects like minerals, fossils, plants, etc. that are also displayed in museums. In the field of medical physics, old instruments and equipment are example artifacts as illustrated here.

A comprehensive knowledge of these artifacts provides an understanding of the foundation, innovations, and developments of medical physics and the contributions of our many pioneers, from Roentgen up to more recent times.

Physical museums and displays in institutions (especially physics departments) around the world are preserving many valuable artifacts from the past.

The reality is that *artifacts* are continuing to be created during the times of our careers.



Because of the dynamic nature of medical physics and clinical applications many of the instruments and systems, both diagnostic and therapeutic, that we have experience with, have, or are becoming *artifacts* and need to be preserved for future generations to learn about.

A major challenge is that current physical museums and academic institutions do not have the resources, especially space, to preserve and display many of these more recent artifacts.

Accepting that reality opens the opportunity for medical physicists living now to become "historians" and preserve the artifacts that were used, and at their institutions in more recent years. Not in physical museums, but with virtual exhibits.

Some examples from my personal experience will be shown here as examples.

III. Museums

Museums are almost "magical" places, that at least in our minds, can take us back into the past, or even into the future. They provide *learning spaces* in which people can interact with and explore objects and events in guided learning experiences. *Museums* are collections of e*xhibits.* Generally, each exhibit provides an opportunity to focus attention on a specific item or topic.

The two major types of museums are *physical* and *virtual*. It is the long established, and often large *physical museums* that provide us with access to the largest collection of instruments and equipment of the past, but these have several limitations, including expense and access limited to those who can physically visit. *Virtual museums* are becoming more significant and valuable in several ways and is the topic of this article.

Physical Museums

Physical museums, often referred to as "brick and mortar" are usually in buildings and the exhibits contain physical objects. They are the institutions that have enriched our society for centuries by preserving and presenting elements of our history and heritage, connecting us to the great inventers and artists in the world, the opportunity to visually visit the many societies, cultures, and regions of the world, observe and learn about many, many natural species, and their roles in our environment, and much more. A major role of physical museums has been *collecting and preserving, archiving*, physical objects and items that have potential historic, scientific, or artistic value. They can range in size from one exhibit in the Physics Department of a university displaying their old instruments or equipment up to some of the world's largest.

- The Smithsonian on the web at: https://www.si.edu
- Deutsches Museum on the web at: https://www.deutsches-museum.de/en

There are also many museums around the world that provide exhibits specifically on medical physics, radiology, and related topics that can be found through this website: https://www.radiology-museum.be/DOX/links_andere_collecties.pdf.

In addition to the preservation and presentation of history and arts, many museums provide opportunities, especially for young people, to engage, explore, and learn about modern science and technology.

Virtual Museums

Modern digital technology for creating, processing, and managing images, especially the internet, provides the infrastructure for *virtual museums.* In virtual museums physical objects are represented with images along with supporting documentation that can be viewed and studied from anywhere in the world. This provides many opportunities and values for preserving and passing on our medical physics history and heritage. Physicists, and especially Medical Physicists, practice their profession using a variety of physical devices, instruments, and equipment for medical procedures. All of these have evolved over the years. These devices from the past, now recognized as *artifacts*, are major elements of our history and heritage. While some physical museums have the actual physical items, instruments, equipment, etc. on display, it is the virtual museums that provide an opportunity for physicists and other interested persons anywhere in the world to view and learn about these elements of our rich history and heritage.

The value of a museum, both physical and virtual, in providing an effective learning experience depends on the design and content of the individual *exhibits.* There are many different designs of museum exhibits, depending on what is being presented. Many, especially looking to the past, focus on objects that are of historic significance, generally designated as *artifacts.* Other exhibits connect us with events, activities, procedures, systems, etc. that are more comprehensive than focusing on individual objects.

Connecting and Experiencing the Past

The traditional and major purpose of many museums is to connect with items and events that are the elements of our rich history and heritage Museums consist of *collections* of *exhibits* containing *artifacts* (items and objects from the past that are of historical significance). To be of significant educational value, each exhibit should provide information about the artifacts describing their origin, characteristics, applications, and perhaps their historical significance. Along with providing exhibits, a major function of museums is to collect and *archive* (store and preserve) *artifacts and can* have large collections of artifacts in addition to those in the exhibits.

Museums usually focus on specific topics including art, nature, science and technology, cultures, and regional histories.

Our interest is in museums for preserving and providing access to the history of Medical Physics and clinical applications. Over the years, the practice of Medical Physics, especially Clinical Medical Physics, has used a variety of instruments and equipment that has evolved with the many developments in technology. The technology, instruments, and equipment of the past is a significant part of our history and heritage, in several respects. It gives us insight into how medical physics was practiced and especially its contributions to clinical medicine, both diagnostic imaging and radiation therapy. The opportunity to physically interact with, at least visually, the item of the past provides a special opportunity to in our minds "experience" and learn about our professional history and heritage.

A longstanding and continuing challenge for medical physicists and historians is providing meaningful exhibits that have good educational value and are accessible to individuals, especially medical physicists, wherever they might be in the world. This is with the two major types of museums: *physical* "brick and mortar" in buildings and *virtual* museums on the internet. Each type of museum has both its special values, and its limitations. A factor that contributes to the value of a specific museum, both physical and virtual, is the characteristics and quality of the exhibits. For maximum value and exhibit should be more than just a display of artifacts. Displaying artifacts without supporting information is one of the limitations of many museums. This generally does not have the resources to develop and display the additional information but is valuable for showing what old items looked like and demonstrating that they are being preserved.

Medical Physics Virtual Museums provide two major opportunities. One is the ability to explore and connect with items and events of the past that are elements of our rich history and heritage displayed in virtual museums anywhere in the. World. The other is the opportunity for us medical physicists today, to participate in the preservation of our history by creating exhibits for virtual museums. This can be from our memories and experiences from the past, old instruments and equipment at our institutions, and other items of historical significance we have collected and saved and would like to show and discuss with others. We now consider this opportunity with an emphasis on the characteristics of exhibits that contribute to their educational value.

Exhibits, both physical in "brick and mortar" museums and virtual on the internet are major resources for preserving and exploring the history and heritage of medical physics and related topics, especially clinical applications.

IV. Libraries and historical publications

A distinction is made between Museums and Libraries. Both are significant in the preservation and providing access to history. History is published in a variety of books and journals that are available in *Libraries*, both physical and online. A major resource for exploring the history is the journal: *Medical Physics International History Series* online at: www.mpijournal.org/history.aspx.

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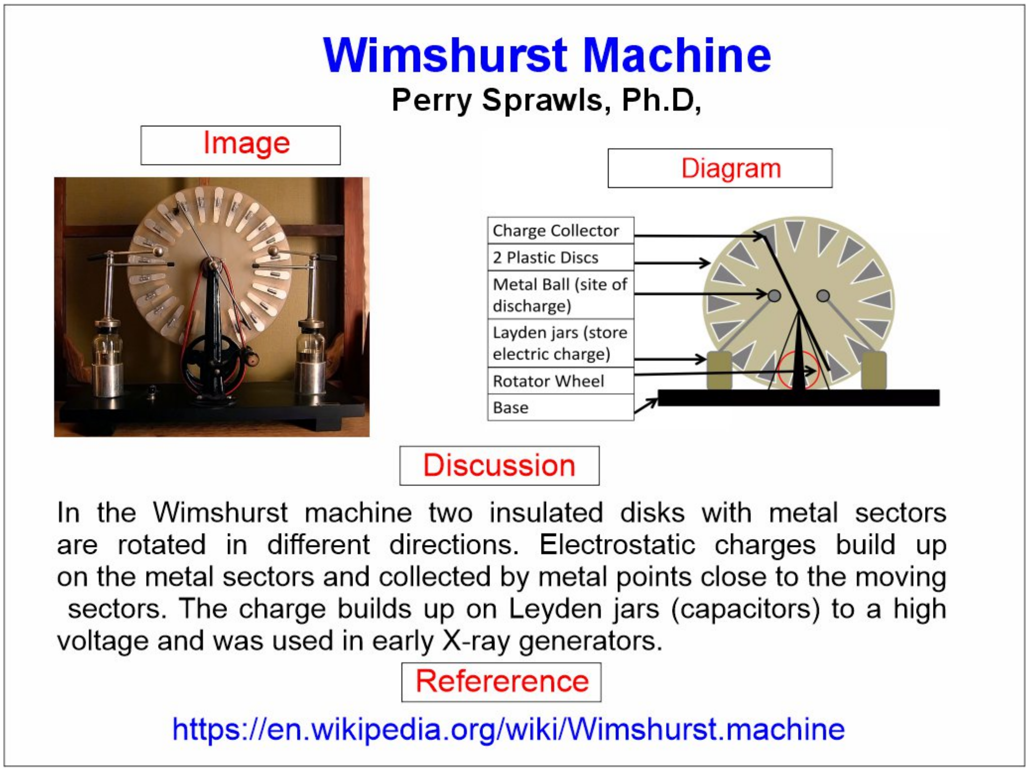
V. Effective exhibits of artifacts

An *effective exhibit* is much more than just displaying an artifact or *image* of an artifact (instrument, equipment, etc.). An effective exhibit should provide a comprehensive *visually based* learning experience, displaying the artifact and providing related details.

This is through physical interaction with the artifact, usually visual, along with text and diagrams to enhance the learning experience. References or links to other sources, especially publications, provide more detailed information and add value.

The example shown here is an exhibit of a Wimshurst Machine (used in the early days to provide high voltage for x-ray production) It combines four factors to convey "the full story".



Sensory Interaction with Objects

A major value of a *museum exhibit* is providing a physical connection between a person and artifacts. This is most often a visual connection but sometimes the opportunity to touch and explore in more detail. In physical museums the interaction with the exhibit is generally for a short time and often when standing. The first need is for the exhibit to attract attention. A posted title for the exhibit might help, but usually it is the ability to view the item or condition, either directly or virtually with images that establishes an interaction and attracts attention.

The effect of viewing an object is it contributes to the formation *of sensory conceptual knowledge* in the mind including many physical characteristics that cannot be conveyed in any other form. When an item is of historical significance, viewing it helps connect us to the times and events in which it was involved.

However, just viewing an item, especially complex items, like the Wimshurst Machine, does not provide for an understanding of how and item functions or its applications. its many characteristics, functions, and applications. For that additional information is needed.

Functional Diagrams and Illustrations

Diagrams and illustrations, like often used in textbooks and classroom teaching, can provide valuable illustrations of how artifacts (instruments and equipment) function and are used.

Discussion with Text

Learning by viewing an item can be enhanced if it is guided by text calling attention to specific features and adding additional details and information. This is what we do in classroom teaching. Exhibits benefit from a relatively short discussion, especially discussion that focuses on the characteristics of the item. For physical exhibits when the viewer is usually standing, the discussions should be short and "to the point",

References, Especially Online References

With the limited information that can be displayed in an exhibit, links to references with additional details add value. Online references are especially useful as they can be viewed as an extension of the exhibit. For the Wimshurst machine here is an example: https://www.youtube.com/watch?v=XMO2NGrW1mU&ab_channel=HistoryofScienceMuseum.

Some virtual museums that provide exhibits with images, discussions, and some with references are:

- Oak Ridge Associated Universities (ORAU) Museum of Radiation and Radiology
  On the web at: https://www.orau.org/health-physics-museum/index.html.

- University of Nebraska Physics and Astronomy Department Museum
  On the web at: https://www.unl.edu/physics/historical-scientific-instrument-gallery.

- The Cathode Ray Tube site, *150 years of CRT evolution.* The Dutch collection.
  On the web at: https://www.unl.edu/physics/historical-scientific-instrument-gallery.

- Museum of X-Ray Tubes of Opole University of Technology
  On the web at: https://muzeauczelniane.pl/en/museum-of-the-opole-university-of-technology-and-x-ray-tubes/.

- Dr. Zahi Hakim Museum
  On the web at: https://medicine.lau.edu.lb/related-entities/zahi-hakim-museum/collection/.

- The AAPM Virtual Museum
  On the web at: https://museum.aapm.org/.

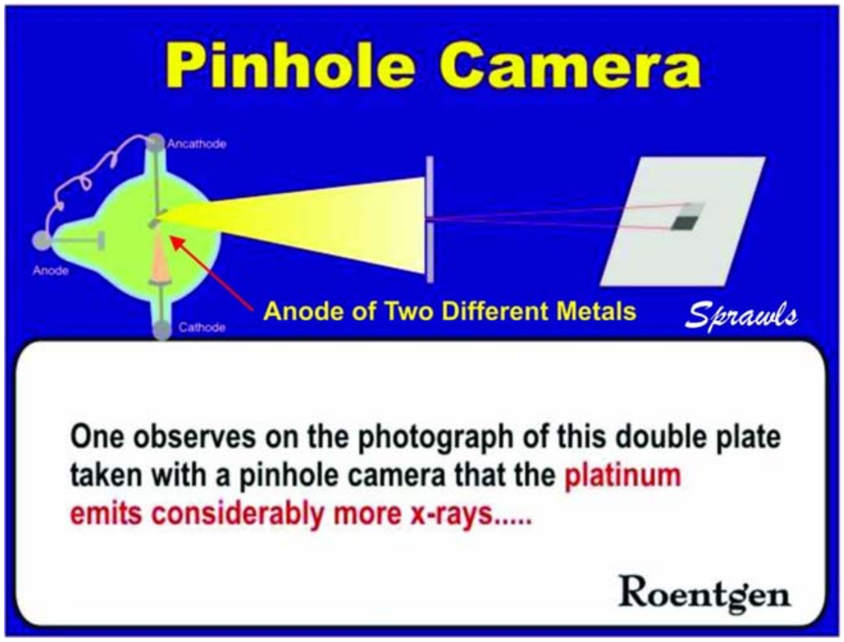
VI. Exhibits of historical activities and events

It is not just the objects, *artifacts,* that represent our history, but also many activities and events that are historically significant. These can be represented by pictures, photographs or drawings illustrating the activity. Labels are added within the pictures or brief legends. Text is added to describe the activity and its historical significance. For historical events where there are no available pictures, illustrations for exhibits can be created from published descriptions, Roentgen's discovery, and extensive research on the characteristics of "a new kind of rays" is an example shown below.

An effective exhibit is one that "takes us back in time" and enables us to, *in our mind*, be present and observe events.

Roentgen's Discovery and Research

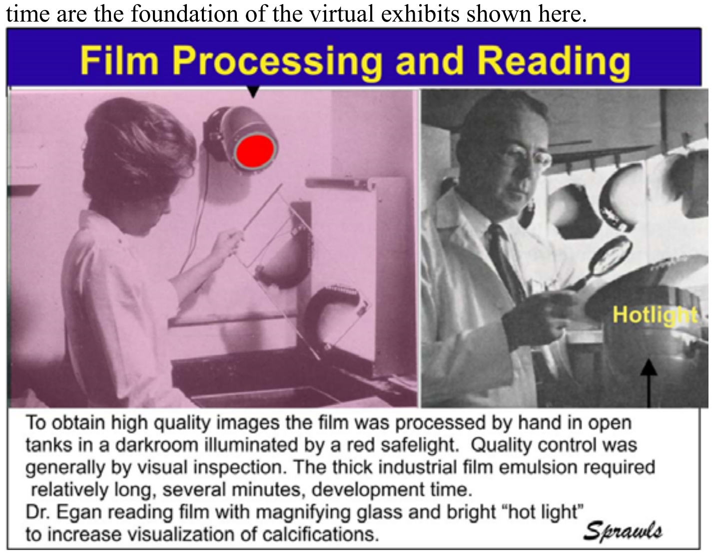
The discovery of a "new kind of radiation" and intense research to determine its characteristics by Prof. Wilhelm Roentgen was the beginning of medical physics and clinical applications of radiation as we know it today. The results of his research were described with words in several publications but without illustrations. To help "take us back in time" and observe the experiments, a series of visuals have been created and published as a virtual exhibit as illustrated here.

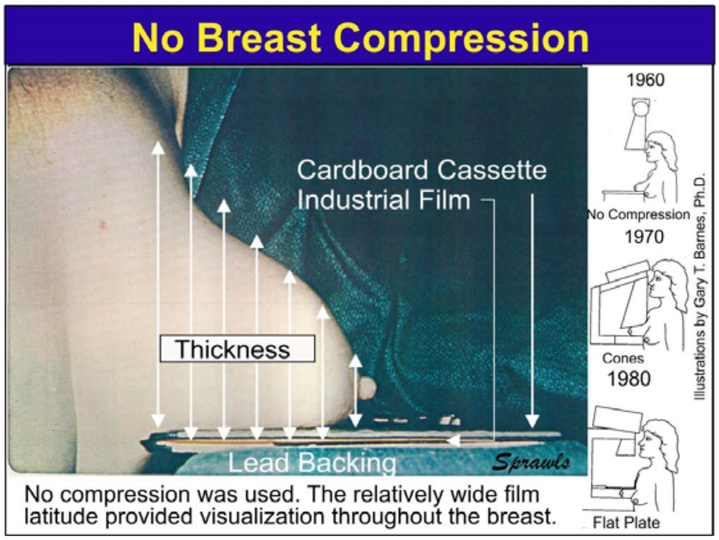


This is one of the series of exhibits in the virtual museum display at: https://museum.aapm.org/exhibit/01-roentgen-discovery-and-research/.

The Early Developments in Mammography

Early in my career, I was conducting research and developing clinical applications in mammography in collaboration with Dr. Robert Egan, generally recognized as the father of mammography, especially in America. The combination of memories and artifacts saved from that time are the foundation of the virtual exhibits shown here.





The series of exhibits on this topic can be viewed at: https://museum.aapm.org/exhibit/06-mammography/.

VII. CREATING AND PUBLISHING EXHIBITS

Virtual museums provide an opportunity for individuals, institutions, or organizations to contribute to the preservation and presentation of the history of medical physics and related clinical applications. It is a special opportunity for medical physicists, especially senior medical physicist, with years of experience to use their memories along with their collections, or "archives," of items used during their careers that have historical significance, both now and in the future. This includes preserving the history of physical instruments and equipment *that will not be placed in physical museums,* along with activities and events that occurred in the past. Preserving history is not just looking back into the past, it also includes the preservation of more recent medical physics items, activities, and applications.

A creation can consist of a single exhibit, or visual illustration with supporting information, or a series of exhibits on a specific topic.

Academic Institution Historical Websites

Many academic institutions and physics departments have history sections on their websites. These could be appropriate for posting virtual exhibits relating to developments and activities by faculty and staff that are, or will be, of historical significance.

The AAPM Virtual Museum

The Virtual Museum of the AAPM (American Association of Physicists in Medicine) provides a place where individual medical physicists can display exhibits, they develop.

For information on contributing exhibits please go to: https://museum.aapm.org/contact/.

VIII. MEDICAL PHYSICISTS AS HISTORIANS AND ARCHIVISTS

Traditionally, it is professional historians along with museum curators and archivists that collect, preserve, and display representations of physical items and events that are of historical significance. These are in physical displays and museums around the world.

Now, the technical capability to create *virtual exhibits* and publish manuscripts (like this one) provides the opportunity for any interested medical physicist to become a historian and archivist, especially in relation to the practice and applications of medicine during their careers. In this respect, we medical physicists have the advantage of experiencing or observing this era in the continuing evolution and developments in medical physics and clinical applications. We often have the comprehensive knowledge and perspective to create exhibits and write manuscripts that can provide interesting learning experiences for future generations.

Historical Manuscripts

The journal, *Medical Physics International History Series*, publishes articles on the history of medical physics and related clinical applications. On the Web at: http://www.mpijournal.org/history.aspx.

Virtual Exhibits

This article provides guides for designing and examples of *effective virtual exhibits*. The creation and posting of exhibits can be a significant contribution to preserving our history, and a rewarding personal experience.

About The Author

Dr. Perry Sprawls

Perry Sprawls, Ph.D. is a clinical medical physicist and educator in medical imaging physics and clinical applications.

A major interest and activity have been the history of medical physics and related clinical activities. Much of this history, the developments, and innovations of the imaging modalities, mammography, CT, MRI, and Digital Radiography, occurred during his 50+ year career working with each as a clinical medical physicist. It is this experience that provides the background and knowledge to help preserve and share this history through publications (sprawls.org) and development of virtual exhibits. He has served on the History Committees of the AAPM and IOMP with an emphasis on encouraging other medical physicists to participate in the historical process. This also continues in his role as Founding Co-Editor of the *Medical Physics International* Journal History Series.

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SCENES FROM THE PAST
X-RAY MANIA: THE X RAY IN ADVERTISING, CIRCA 1895

E. S. Gerson[1], P. Sprawls[2]

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Sprawls Educational Foundation, www.sprawls.org

I. Introduction

It is interesting how a seemingly innocuous event can lead inexorably to a quest that consumes many hours of one's life. Such was the case many years ago when, at a flea market, I (E.S.G.) stumbled across a sign advertising "X-ray Headache Tablets". I decided to see if I could find an actual bottle of patent medicine. Shortly thereafter, at an antique show in central Massachusetts, I went from booth to booth, asking dealers of apothecary or country store memorabilia about X-ray Headache Tablets. One dealer from upstate New York responded that he thought he had such a bottle back at home. A few weeks later, I received a letter in which he apologized for having misled me. He had been mistaken. Instead, he had a box of X-ray Prophylactics, which I purchased. The question was obvious: What could x rays have to do with headache tablets or prophylactics? Thus began a quest to collect and otherwise document other "x-ray" products, dating from the end of the 19th and the beginning of the 20th centuries, that attempted to capitalize on the marketing potential ascribed to this new technology.

Why would an advertiser for headache pills or golf balls or stove polish choose to put the word *x ray* on their products? For the same reasons that we see the word *laser* applied to everything from courier services to running shoes: New technologies have an appeal that reaches far into the public psyche. Nancy Knight, a historian of technology, has written about this phenomenon (' 1.). And I have also discussed it with James Twitchell, professor of history at the University of Florida, Gainesville, and with Joseph J. Corn, professor of the history of technology at Stanford University, California. These and other writers have looked at the common mindset that responded to the x ray as a powerful, potent metaphor and at advertisers who played—in sometimes bizarre ways—off this public perception.

One explanation for the marketing phenomenon was simply that, for at least a short period after the discovery of x rays in 1895, everything about the new rays was dazzling and fascinating to the public. Knight discussed the immediate and widespread "x-ray mania" that followed the announcement of the amazing "new light":

In the last century [19th], some futurists dreamed of great breakthroughs but could not articulate the content or form of the medical miracles. These optimists would not have to wait long for inspiration. With the discovery of x-rays, the basis for the first "miracle machine" in clinical medicine, a change occurred in medical dreams. In the first months after Roentgen's announcement, the medical profession and the public were treated to predictions of immediate miracles. X-ray mania began early and grew quickly. People reacted to the discovery of the x-ray in different ways. There was an immediate popular response that spawned the sort of cultural manifestation common to fads. X-rays appeared in advertisements, songs and cartoons. X-rays, many believed, would become a part of everyday culture, from henhouses to the temperance movement, from the detection of flaws in metal to the analysis of broken hearts. Hopes for new technology reflected a wide spectrum of contemporary concerns. The public learned that x-rays might soon be used routinely for everything from diagnosing pregnancy to raising the dead. The rays represented the miracle cure that someday, with the flick of a switch, might heal a wide range of mortal ills. One author called the field of radiology a "veritable fairyland of science" in which the most extravagant hopes might someday be realized.

II. Visiting the Shops of the Past

The impact of the word X-Ray, for promoting many products would be observed in the different shops, ranging from the pharmacies to the hardware stores. Here in Figures 1-24 we can now look through the old shops and advertisements and reflect on the impact X-Ray had on our society, in addition to being one of the greatest contributions to the practice of medicine.

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

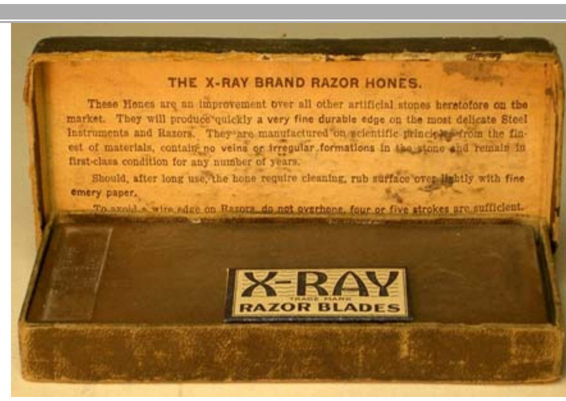

Figure 10

Figure 11

Figure 12

Figure 13

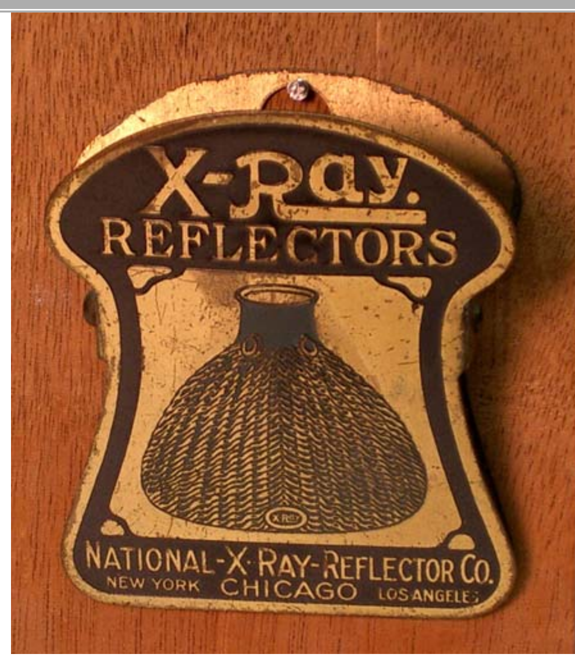

Figure 14

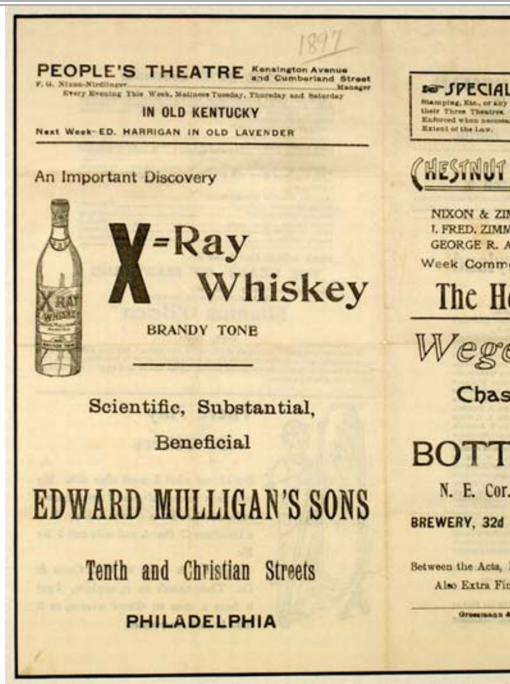

Figure 15

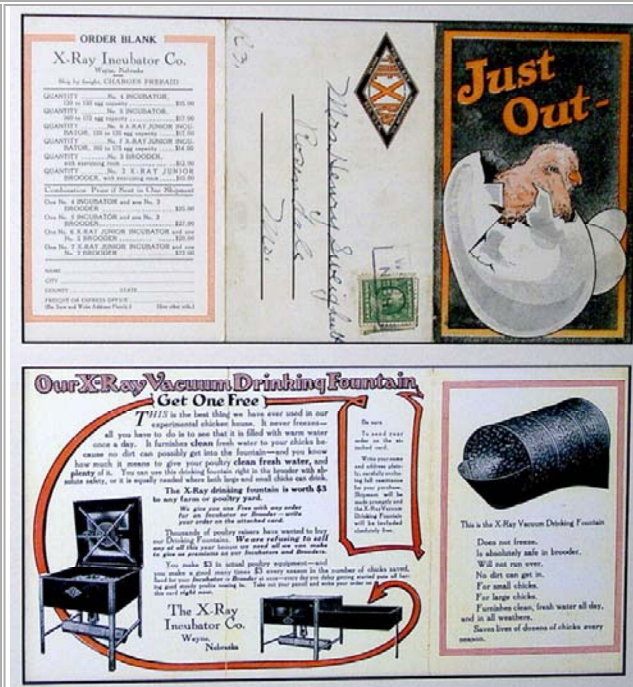

Figure 16

Figure 17

Figure 18

Figure 19

Figure 20

Figure 21

Figure 22

III. Conclusion

The x-ray grabbed the imagination of scientists and the public with great intensity. Scientists focused on its powers to make matter transparent and to cure illness. The public concentrated on its magical ability to see through objects and its miraculous capacity to change the world as they knew it. Together, everyone focused on the x ray as an unexpected technologic advancement that encouraged belief in other similar or even more miraculous advances. Hence, x-ray became exemplary of the better future that all might experience. The x ray extended the normal human senses and promised to improve quality of life. What product would not benefit from such sub-conscious association?

ACKNOWLEDGMENT

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Edwin S. Gerson, M.D., is a Semi-Retired Radiologist practicing in Atlanta, GA, USA. Being a naturally curious radiologist and an inveterate collector was the motivation for developing an extensive collection of items and advertisements that used the name “X-Ray” to promote their products.

Perry Sprawls, Ph.D., is a Medical Physicist with a major interest in preserving and publishing the history of Medical Physics and related applications. This includes serving as Co-Editor of this Journal.

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BRIEF HISTORICAL OVERVIEW OF THE INTERNATIONAL CONFERENCES ON MEDICAL PHYSICS (ICMP) 1965-2024

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Abstract

The paper gives a brief historical overview of the beginning and development of the International Conferences on Medical Physics (ICMP) in the period 1965-2023 - a very important activity of the International Organization for Medical Physics (IOMP), related to the global development of medical physics. It further describes the beginning and development of the World Congresses (WC) on Medical Physics and Biomedical Engineering in the period 1979 – 2022. The paper also briefly mentions the International Conferences on Medical Physics Education, which further supported the international development of the profession. Finally the paper emphasizes the need of close cooperation of the Regional Conferences and Congresses with the ICMP and WC.

The beginning of the International Conferences on Medical Physics

International Conferences on Medical Physics (ICMP) are very important meetings in the profession and since the formation of IOMP in 1963 one of the powers of the Organisation was "To organize international meetings and conferences". The first ICMP was organised in Harrogate, UK (8-10 September 1965). This first ICMP was a great success, gathering over 500 medical physicists from 24 countries. Patron of the Conference was Sir John Cockcroft (laureate of Nobel Prize in Physics, 1951), President of the Conference was Prof. W Mayneord (IOMP President at the time), Chair of Scientific Com was Prof. J Rotblat and Secretary was Mr G Innes. In an Annex to this MPI-HE issue we present the Book with Abstracts from this 1st ICMP, in order to show to the readers the state of art of the scientific development in the profession in mid-1960s as a basis for assessing the progress in medical physics in the following 60 years.

Four years later the 2nd ICMP was organised in in the USA (Boston, USA, 10-14 August, 1969) with Organisers E. W. Webster, John Laughlin and Lauriston Taylor.

The venues of the next ICMPs continued to be associated with the Founding Societies of IOMP (from UK, USA, Sweden and Canada). The 3rd ICMP was in Goteborg, Sweden (30 July – 4 August 1972) with Organisers: Roland Kardefors, Ingemar Petersen, and Robert Magnusson. The 4th ICMP was in Ottawa, Canada (25-30 July, 1976), organised by Paul Phalzner from Ottawa Cancer Clinic. This ICMP has specific importance, as at that Conference a decision was taken the next 5th ICMP (planned to be in Jesrusalem) to be made to coincide with the International Conference of Biomedical Engineering, thus forming the basis of future World Congresses of Medical Physics and Biomedical Engineering (and basis for the formation of the Union between medical physics and biomedical engineering organisations – the International Union for Physical and Engineering Sciences in Medicine (IUPESM).

Thus the 5th ICMP took place in Jerusalem, 19-24 August 1979, organised by the Israeli Association of Physicists in Medicine and International Federation for Medical and Biomedical Engineering. Indeed this joint International meeting (the 5th for the medical physicists and the 12th for the biomedical engineers) was accepted as the 1st World Congress for both professions.

ICMP and World Congresses in Medical Physics and Biomedical Engineering

Following the joint international meetings of medical physicists and biomedical engineers in Jerusalem 1979, for about 25 years the ICMPs were coinciding with the World Congress (WC):

-6th ICMP and 2nd WC in Hamburg, Federal Republic of Germany (5-11 September 1982) with Organizer: Universität Hamburg, D. Harder (German Society for Medical Physics - DGMP) and W. Bleifeld (German Society for Biomedical Technology).

-7th ICMP and 3rd WC in Espoo, Finland (11-16 August 1985); Organizer: Finnish Society for Medical Physics and Medical Engineering.

-8th ICMP and 4th WC in San Antonio, USA (6-13 August, 1988); Organizers: Gary Fullerton, Robert Nerem, and David Kopp. At this event was inaugurated the IUPESM Award of Merit.

-9th ICMP and 5th WC in Kyoto, Japan (7-12 July, 1991); Organizers: Hiroshi Abe, WC President and F. Kajiya, Secretary General.

-10th ICMP and 6th WC in Rio de Janeiro, Brazil (21-26 August 1994); Organizers: Carlos Eduardo de Almeida and Ronney Panerai (Co-Presidents).

-11th ICMP and 7th WC in Nice, France (14-19 September 1997); Organizers: Pierre Aletti, J-P Moucucci, and Rigaud (Co-Presidents).

-12th ICMP and 8th WC in Chicago, USA (25-28 July 2000); Organizers: William Hendee and Al Potvin (Co-Presidents). At this event was inaugurated the IOMP Marie Curie Award.

-13th ICMP and 9th WC in Sydney, Australia (19-24 August, 2003); Organizers: Barry Allen and Nigel Lovell (Co-Presidents). At this WC and ICMP the IOMP President A Niroomand-Rad and the ExCom decided to have additional ICMPs in the period between World Congresses. This was related to the fact, that the IOMP Regional Organisations (Federations: EFOMP in Europe; AFOMP in Asia; SEAFOMP in South-East Asia; MEFOMP in the Middle East; ALFIM in Latin America and the Carribean; later FAMPO in Africa) had already started to have their own Regional Medical Physics Conferences and IOMP wanted to merge its ICMP with some of these. This way the 14th ICMP was held together with EFOMP in Nuremberg, Germany (14 – 17 September 2005, together with EFOMP); Organizer: Willi Kalender.

Thus the following 10th WC was associated with the 15th ICMP (together with the Conferences of AFOMP and SEAFOMP) in Seoul, South Korea (27 August 27 to 1 September 2006); Organizers: Kim Sung-Kyu and Tae-Suk Suh (Co-Presidents). At this event was inaugurated the IOMP Harold Johns Medal Award.

The 16th ICMP was organised together with MEFOMP in Dubai, United Arab Emirates (14-16 April 2008); Organizers: Jamila Salem Al Suwaidi, Emirates and Peter HS Smith, UK.

The 17th ICMP was held together with the 11th WC (and with EFOMP) in Munich, Germany (7-12 September 2009); Organizers: Wolfgang Schlegel and Olaf Dossel (Co-Presidents). At Munich the IOMP ExCom decided the next ICMP to be together with ALFIM in Brazil, while the following ICMP in 2013, celebrating the IOMP 50th Anniversary, to be in the UK (together with EFOMP).

The 18th ICMP was organised together with ALFIM in Porto Alegre, Brazil (17-20 April 2011); Organizer: Ana Maria Marques da Silva.

The 19th ICMP was associated with the 12th WC (together with the Conferences of AFOMP and SEAFOMP) in Beijing, China (26-31 May 2012); Organizers: Depei Liu, Yubo Fan, and Yimin Hu (Co-Presidents).

The 20th ICMP was in Brighton, UK (1-4 September 2013); Organizers: IOMP, IPEM (the UK society) and EFOMP, Peter Jarritt (UK), William Hendee (USA). At this event was inaugurated the IOMP Fellowship scheme.

The 21st ICMP was associated with the 13th WC (together with the Societies from North America – AAPM and CAMP) in Toronto, Canada (7-12 June 2015); Organizers: David Jaffray and Tony Easty (Co-Presidents).

The 22nd ICMP was organised together with SEAFOMP and AFOMP in Bangkok, Thailand (9-12 December, 2016); Organizer: Anchali Krisanachinda, Tae-Suk Suh and Slavik Tabakov (Co-Presidents). At this event were inaugurated the IOMP John Mallard Award and the IDMP Award. From this event the Abstracts of the ICMPs were publishjed by the free online IOMP Journal Medical Physics International, thus keeping in one place a record of the constant progress of the profession.

The 23rd ICMP was associated with the 14th WC in Prague, Czech Republic (3-8 June 2018); Organizer: Jaromír Cmíral and Libor Judas (Co-Presidents).

The 24th ICMP was organised together with ALFIM in Santiago, Chile (9 – 12 September 2019); Organizer: Jose Luis Rodriguez, Rodolfo Alfonso and Madan Rehani (Co-Presidents).

The 25th ICMP was associated with the 15th WC in Singapore (12 – 17 June, 2022); Organizer: Lip Teck Chew (IOMP), Chwee Teck Lim (IFMBE), Co-Presidents. Due to the pandemic the planned WC for 2021 was postponed to 2022. Also due to the pandemic situation this was the first hybrid (in person and virtual) Congress (and ICMP) in the profession.

The 26th ICMP was organised together with AFOMP and SEAFOMP in Mumbai, India (6-9 December 2023); Organisers: D K Aswal, J Damilakis.

The 27th ICM is planned to be during the 16th WC in Adelaide, Australia (29 September – 4 October 2025); Organisers: Eva Bezak and Adrian Richards (Co-Presidents).

International Conference on Medical Physics Education and Training

As seen from the 1st ICMP Book with Abstracts (1965), from the very beginning the Scientific Conferences included subjects related to organisation, profesional development and later education.

The first International Conference dedicated to Medical Physics Education was organised in Budapest, Hungary, 12-14 November 1994; Organisers: C Roberts, S Tabakov, C Lewis and P Zarand, N Richter and I Polgar. The objectives of the Conference (supported by the EU) were to establish the status of medical physics education in Central/Eastern European countries, to increase East/West European cooperation on the subjects and to formulate proposals for the advancement of medical physics education in Eastern Europe. This International Conference attracted participants from 23 countries and triggered the development of medical physics university courses in many of the Eastern European countries. After the Conference reports with the status of medical physics education in Europe were published in a book, wich is included in an Annex to this MPI-HE issue. The book presents a broad picture of the status of medical physics education in Europe in mid-1990s.

Following this Conference three other International Conferences were organised by members of the above team:

-The International Conference on Medical Physics Training in ICTP, Trieste, Italy (24-26 September 1998); Organisers: S Tabakov, C Roberts, A Benini, L Bertocchi;

-The International Conference on Medical Physics e-Learning in ICTP, Trieste, Italy (9-11 October 2003); Organisers: S Tabakov and V Tabakova;

-The International Conference on Medical Physics e-Encyclopaedia in ICTP, Trieste, Italy (23-26 October 2008); Organisers: S Tabakov and V Tabakova. This Conference included 21 Presidents (past and current) of Medical Physics National Societies and International Federations/Organisations.

These pioneering Educational Conferences boosted significantly the interest and development of activities related to professional education and training. This can be seen in the significant increase of new medical physics University programmes as well as in the increase of educational sessions at ICMPs and WCs. For example the WC2003 included 6 sessions and one workshop on MP Education; WC2006 included a dedicated Track with 9 sessions and one Workshop on Education, WC2009 included a Track with 7 sessions and two Workshops on Education; WC2012 included 6 sessions and 3 Mini-Symposia, etc. These activities were also related to the initiation of other international activities on medical physics education/training:

-The transformation of the International College on Medical Physics at ICTP Trieste into a "Train-the-Trainer" activity in 2002, what continues successfully now over 20 years;

-The IOMP Project "Model Curricula in Medical Physics" (2006-2009), led by P Sprawls and S Tabkov, which later trigerred the IAEA project (and related Guide) TCS 56 "Postgraduate Medical Physics Academic Programmes";

-The book Medical Physics and Engineering Education and Training, 2011, Edited by S Tabakov, P Sprawls, A Krisanachinda, C Lewis, (2011), ISBN 92-95003-44-6, ICTP, Trieste, Italy

-The formation of the IOMP Journal Medical Physics International in 2013, dedicated to educational and professional development (Founding Editors S Tabakov and P Sprawls), which quickly established itself as one of the well respected journals in the profession.

Conclusion

This brief overview is based on the IOMP History Tables and presents additional information about the International Conferences and World Congresses, based on the authors participation in all ICMPs and WCs after 1982 (in most of these as member of the Organising Commtee or the Advisory Board). These Conferences and Congresses provided an excellent support for the progress of the profession and its global spread. Together with these, the IOMP Regional Organisations (Federations) initiated from around 2000 its Regional Conferences (some later named Congresses), which grew and provided further support for the professional development, assiciated with the specificities of the Region/Continent. The largest and most important one currently being the Annual Conferences of the Americal Association of Physicists in Medicine (AAPM), which some times surpass the World Congresses in size and importance. Some Asian and European Congresses also became very large and important activities. It will be important for the ICMPs and the World Congresses to combine with these Regional Congresses in order to reflect not only the Regional development of the profession, but also its global growth and importance for the global healthcare.

Acknowledgements

I would like to express special gratitude to Dr Chris Gibson (Oxford, UK) who in 2013 presented me with the Book of Abstracts of the First ICMP in 1965 (while he was External Examiner of the MSc of which I was Director - the MSc Clinical Sciences in King's College London).

The book with Abstracts if the International Conference of Education (Budapest, 1994) was distribited free all over the world and I am grateful to my Co-Editors and all who contributed to it.

Additional Reading:

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THE EVOLUTION OF VISIBILITY IN MEDICAL X-RAY IMAGING
A HISTORICAL PERSPECTIVE

P. Sprawls[1]

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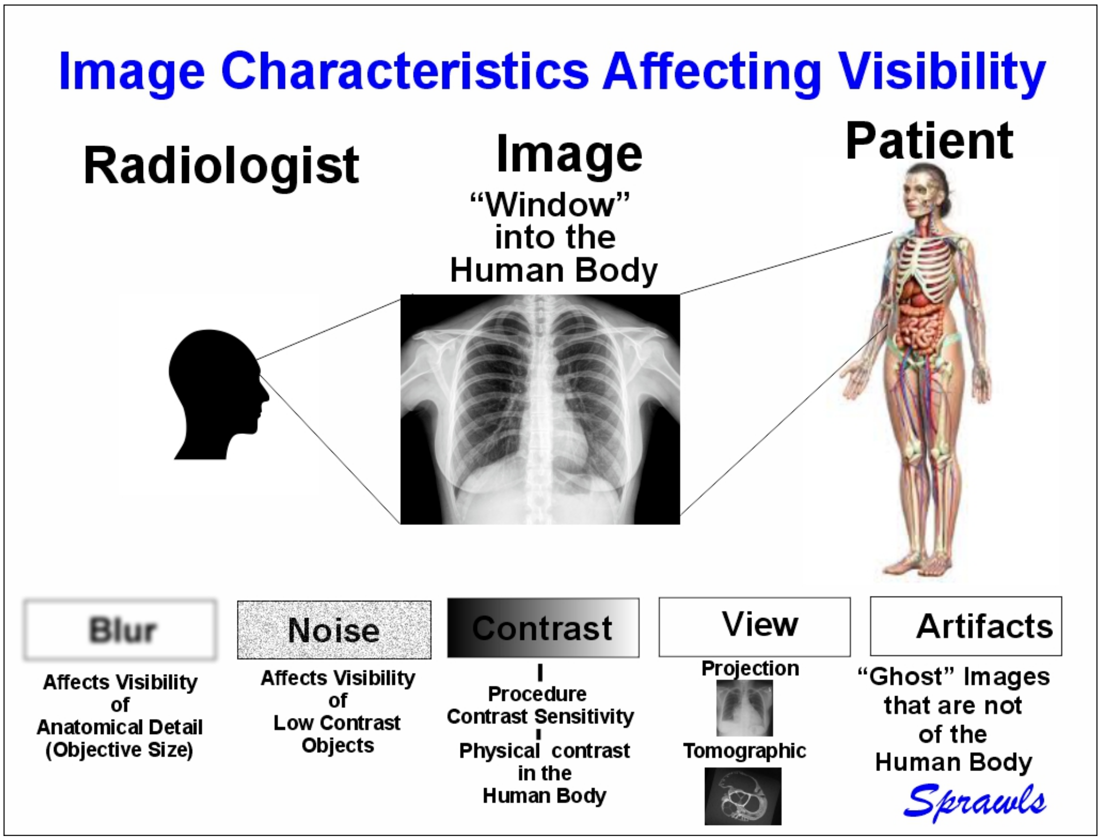
Sprawls Educational Foundation, www.sprawls.org

I. INTRODUCTION



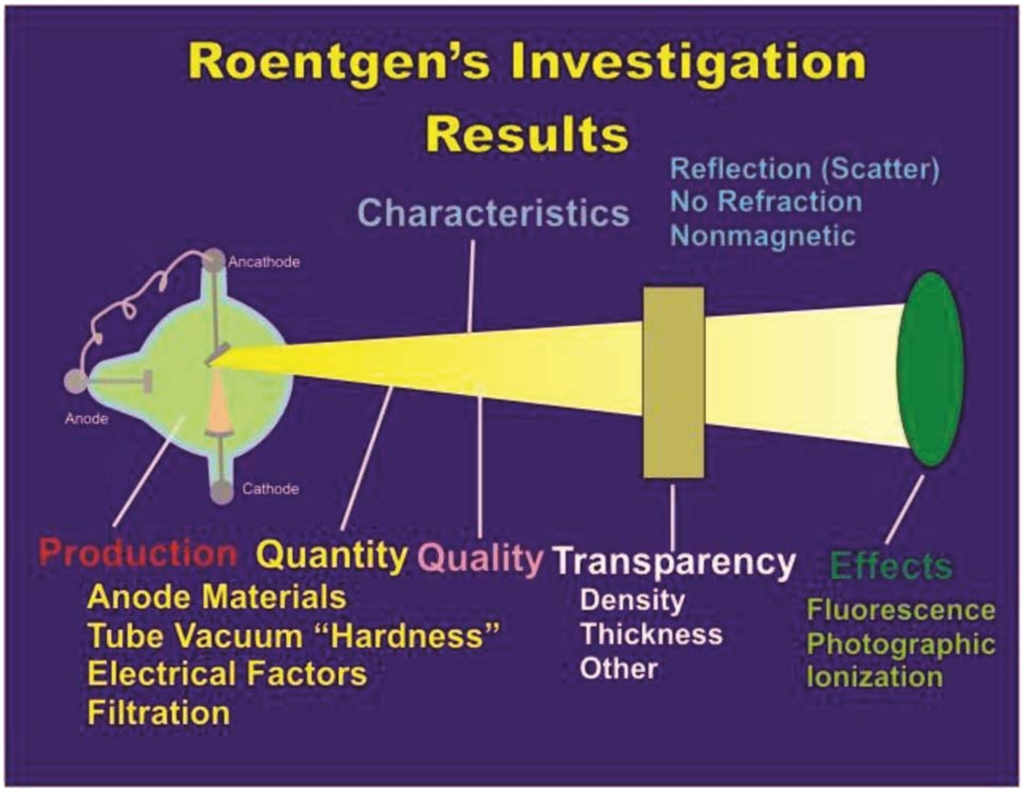
Throughout the course of history, the examination of the human body for diagnosing and treating diseases and injuries was limited to the exterior of the body, except for highly invasive and painful surgeries. This changed in1885 when a physicist, Dr. Wilhelm Roentgen, extended human vision into the human body with the discovery and extensive research on the characteristics of a "New Kind of Radiation" soon to become known as X-rays or Roentgen Radiation.

It was the *visibility* of the internal human body that was to change the course of medicine and become the foundation of the major medical specialty known as Radiology. Roentgenology, or Medical Imaging. The first images produced by. Dr. Roentgen introduced this possibility to the world where of the bones in a hand. They were visible because they were both large and of a different composition (calcium) compared to the surrounding soft tissue, a form of physical contrast.

Visibility, that is the ability to see a specific object or condition with an image depends on a combination of physical characteristics of the image and the imaging procedure as identified above. For well over a century, physicists, often along with engineers and physicians, have invented and developed medical imaging technology and techniques to increase visibility to a much larger range of structures, objects, and conditions in the human body…not just large bones. These developments have in various ways addressed each of the image characteristics that determine and often limit visibility within the body.

II. A NEW KIND OF RADIATION

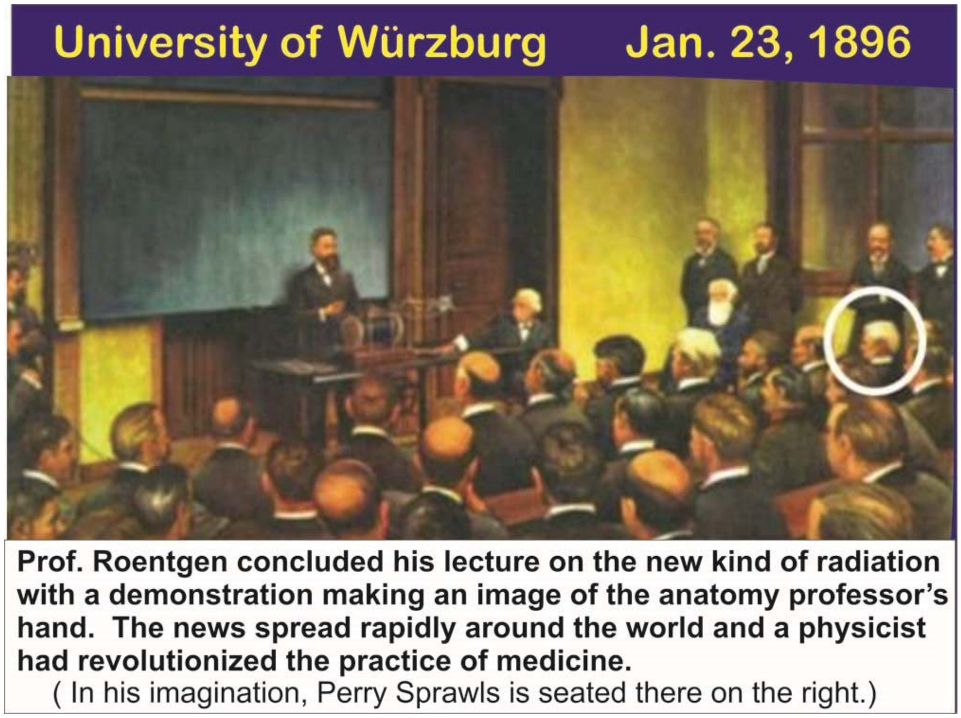
It was not just the discovery of "A New Kind of Radiation" that could penetrate the human body and produce shadow images of the bones that was Roentgen's evolutionary contribution to medicine. It was his extensive research determining the physical characteristics of the radiation summarized here that provided a foundation for physicists, engineers, and other medical professionals to soon begin the development of equipment and imaging methods that would extending the visibility to much more of the body, not just large bones.



The description of this research by Roentgen with illustrations added by Sprawls can be viewed here:

ROENTGEN'S INVESTIGATION DETERMINING THE CHARACTERISTICS OF X-RADIATION
P. Sprawls. MEDICAL PHYSICS INTERNATIONAL Journal, vol.2, No.2, 2014
http://www.mpijournal.org/pdf/2014-02/MPI-2014-02-p435.pdf

Roentgen published the results of his research in several articles (referenced in the above online article) but it was his presentation on January 23.1896 that introduces X-ray imaging for medical purposes to the world.



III. BIOLOGICAL EFFECTS, RISK, AND LIMITATIONS

It was not recognized for some time after the discovery of new kind of radiation, X-rays, that it could interact with and have a variety of biological effects on human tissue…both good and bad. The good effects were to become the foundation of radiation therapy for treating cancer. Unfortunately, there were also bad or undesirable effects that could produce cancer and other determinants to humans, including death. The impact was on both patients and the scientists and medical professionals that worked with the radiation, but in different ways.

Radiation Workers:

It was the professionals working with the radiation over extended periods of time that received lethal exposures. See:

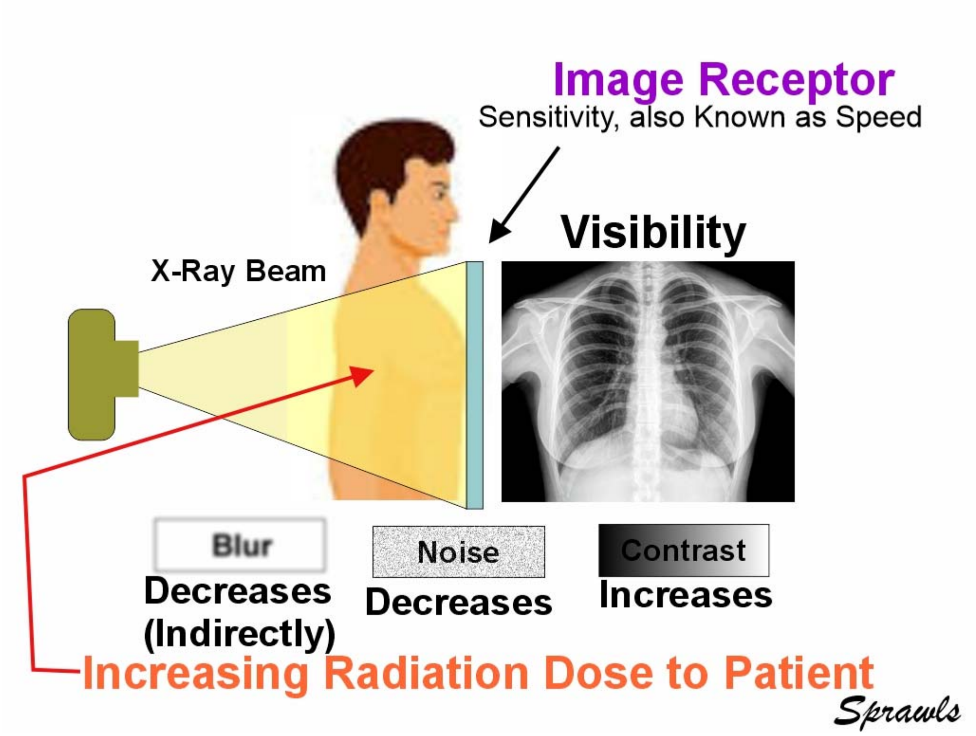
Monument to The X-Ray And Radium Martyrs Of All Nations on the web at:

http://www.mpijournal.org/pdf/2022-SI-08/MPI-2022-SI-08-p1020.pdf.

Patients:

The concern for patients undergoing x-ray imaging procedures was that even though they are exposed to relatively low levels of radiation there is the possibility of increasing the risk or probability of cancer or undesirable genetic effects. These generally have a stochastic relationship to radiation exposure levels without established safe thresholds. Therefore, the effort is to keep the exposure as low as possible to minimize the risk, not to meet some established safe threshold.

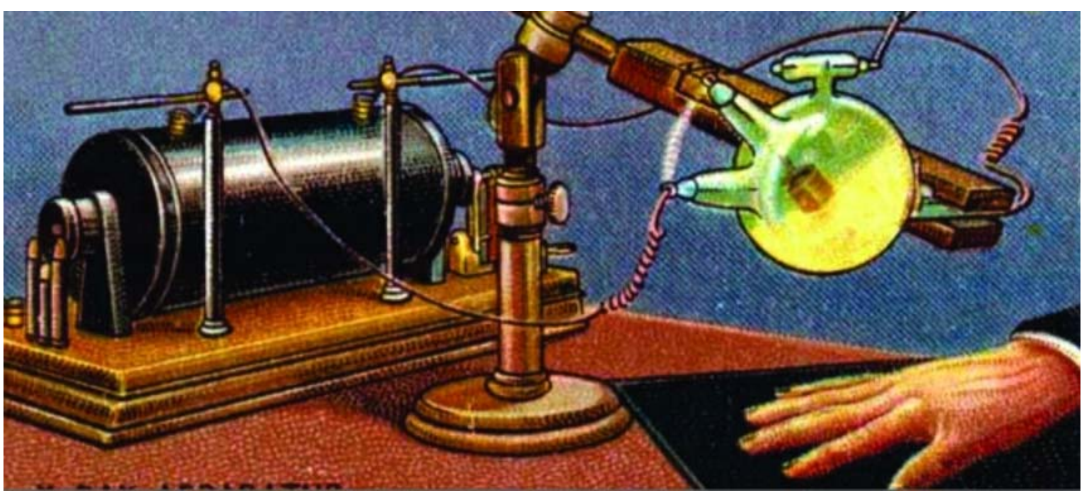
The issue is that reducing the radiation exposure to a patient also reduces the radiation that forms the image and can adversely affect three of the image characteristics that determine visibility as illustrated here.



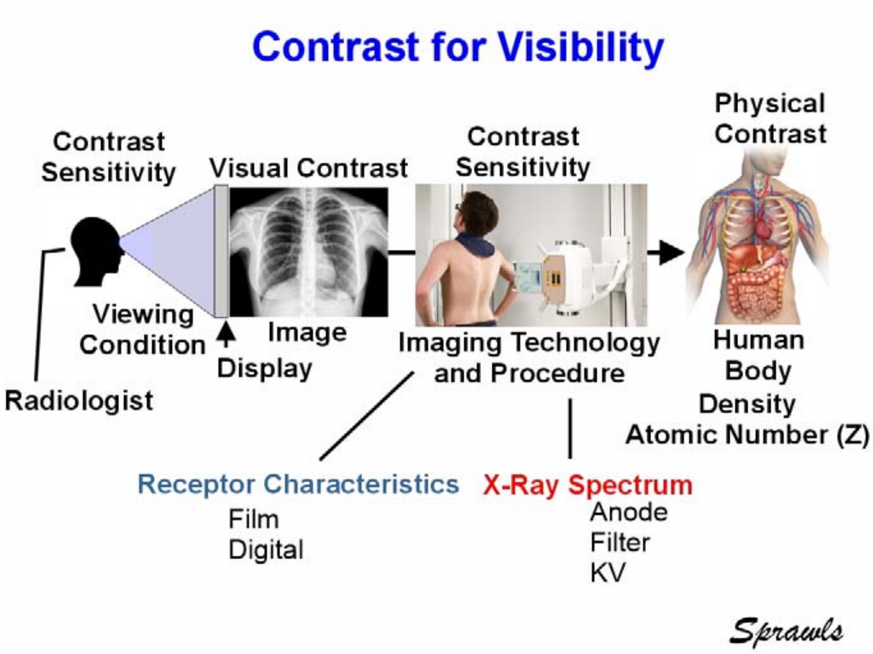
In radiography or general X-ray imaging, as illustrated here, the human body absorbs a major fraction of the radiation in comparison to radiation absorbed by the receptor which determines the characteristic and quality of the image. To increase the exposure to the receptor to improve visibility will result in increased exposure to the patient and presumed increase in risk to cancer and genetic mutations.

IV. In the beginning

At the time of Roentgen's creation of X-ray imaging and its medical applications, the equipment had not been developed for imaging. It was a collection of partially evacuated glass tubes and various high-voltage electrical sources used in physics departments and laboratories for experiments and demonstrations…that just happen to produce X-rays.



V. CONTRAST

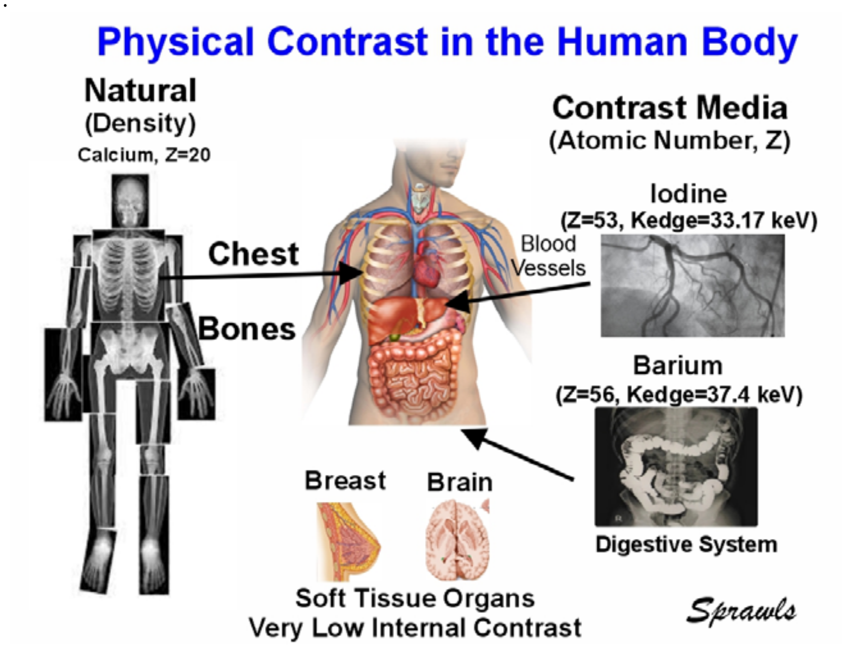


Contrast is the fundamental requirement for *visibility*. An object will only be visible if it has contrast or is physically different from its surrounding area. Then, this physical contrast must be transformed into optical or visible light contrast in an image and then displayed in appropriate conditions so that it is visible to a human, typically a radiologist who can use the visibility of the interior of the body to detect and diagnose diseases and other pathological conditions. As illustrated, the transfer of the physical contrast in the body to perceived contrast by the radiologist is a multi-step and complex process.

The *evolution of visibility* to include a greater range of objects and conditions in the body has resulted from a series of inventions and developments for each of these steps which will now be considered.

Physical Contrast in the Body:

The only objects or conditions that will be visible are those that have some form of *physical contrast* in relation to the surrounding anatomy.



The physical contrast must be one, or both, of the characteristics that control X-ray attenuation, that is density or atomic number (Z). The inherent, or naturally occurring contrast in the body is physical density.

Viewing the Skeleton:

Bones are denser than soft tissues. The higher atomic number of calcium (Z=20) gives bone and effective atomic number (Z=13.8) compared to the effective atomic number of soft tissue (Z=7.4), about the same as water, also contributes to some difference in x-ray attenuation and contrast. Soon after the announcement and demonstration by Roentgen in 1896 physicists around the world who had the tubes and high-voltage sources began imaging bones, sometimes along with medical doctors, and diagnosing and evaluating broken bones…and the practice of medical x-ray was established and changing the world.

The Thoracic Cavity (Chest) Comes into View

Exploring the human body with this new and revolutionary "extension of human vision" was soon underway…especially at first with fluorescent screens (fluoroscopes) to view the images. Now moving past just the bones, it was discovered that the chest cavity and its content was now visible. It was because the lungs partially filled with low-density air provided an excellent background for many of the denser items including cancers and other diseases (tuberculosis), buildup of fluids, the heart, ribs, and much more. The X-ray *image of the chest* was to become the most frequently and routinely performed medical image because of the valuable clinical information it can provide.

Extending Visibility with Contrast Media:

Most of the anatomical systems, other than the skeletal and thoracic, consist of soft tissues and fluids that do not have sufficient variation in density or atomic number to be visible with x-ray imaging. This challenge was met by temporally administering substances, contrast media, that have higher x-ray attenuations because of their specific atomic numbers. Iodine (Z=53) for cardiovascular and urinary system vessels and barium (Z=56) for the digestive system. It is physical, not chemical, characteristics that are significant. Their x-ray attenuation K-edge peaks are in the mid 30 keV range that corresponds to the maximum intensity of a properly adjusted X-ray beam spectrum…more about that later.

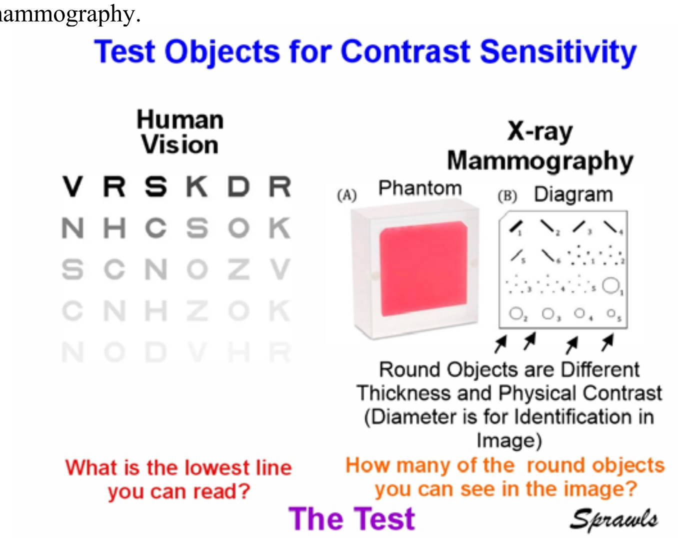
Soft Tissue Contrast:

A continuing challenge to x-ray imaging, and visibility, is that the soft tissues within the various organs, even though they are anatomically and functionally different, do not have the necessary density or atomic number differences to provide contrast for visibility with conventional x-ray imaging methods. These include the female breast and the brain, which is enclosed in a dense skull. These remained invisible for many years until special imaging methods were developed for each and will be considered later.

Imaging Procedure Contrast Sensitivity

Contrast Sensitivity is the characteristic of an imaging process that determines the *range of visibility* in relation to the physical contrast of objects. Specifically, it determines the lowest physical contrast that will be visible. It applies to virtually all imaging processes, including human vision.

Various test objects, sometimes known as phantoms, are used to test or evaluate contrast sensitivity. Two are illustrated here. These tests provide a measure of *relative contrast sensitivity* that are compared to established standards or reference levels for both humans and mammography.



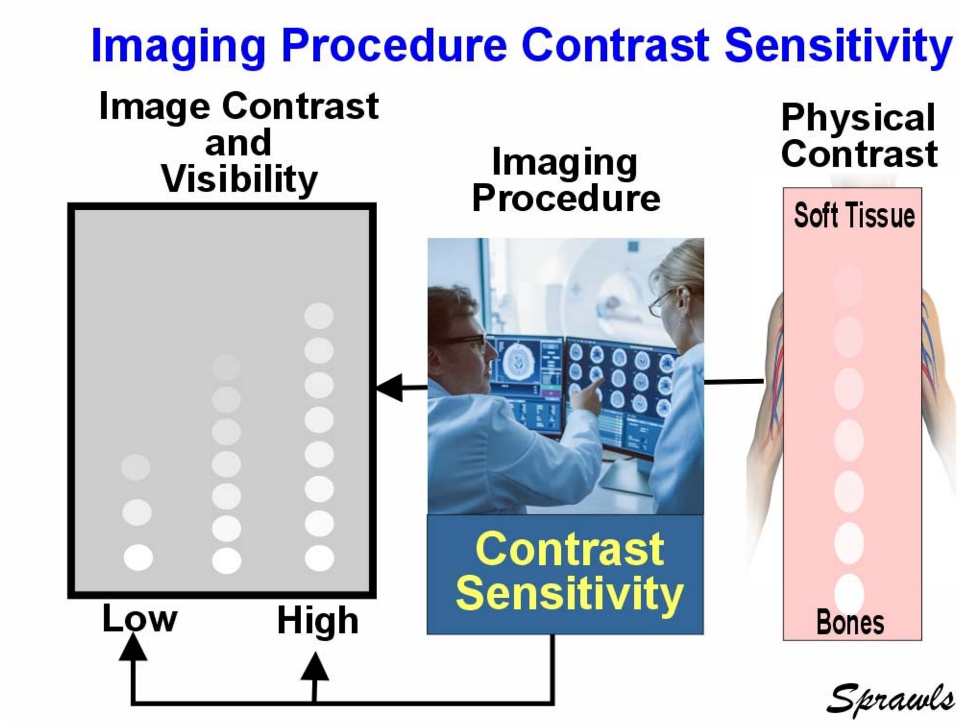
For human vision the test is performed by a physician, usually an ophthalmologist, using the image on the left in which the contrast of the objects (letters of the alphabet) varies with each line. The relative visual contrast sensitivity for a patient is determined by the lowest line (object contrast) they can read.

For X-ray imaging, specifically mammography, the test object, or phantom, illustrated on the right is used by physicists. It contains several groups of objects to evaluate different image characteristics. For contrast sensitivity it is a series of round objects that have varying thicknesses providing different physical contrast. The relative contrast sensitivity is determined by the number of objects visible in an image.

The visibility of low-contrast objects in medical imaging is also affected by *visual noise* that will be considered later. The test described above can also show the effects of noise on visibility.

The contrast sensitivity for a specific imaging procedure is determined by a combination of factors including the design and technical capabilities of the imaging equipment and the control and adjustment of the variable technical factors for each patient imaging procedure.

Over the years, *visibility* of the interior of the human body has dramatically expanded with discoveries, inventions, and developments of technology and imaging methods that increased contrast sensitivity. Here we consider the general concept and then the details.

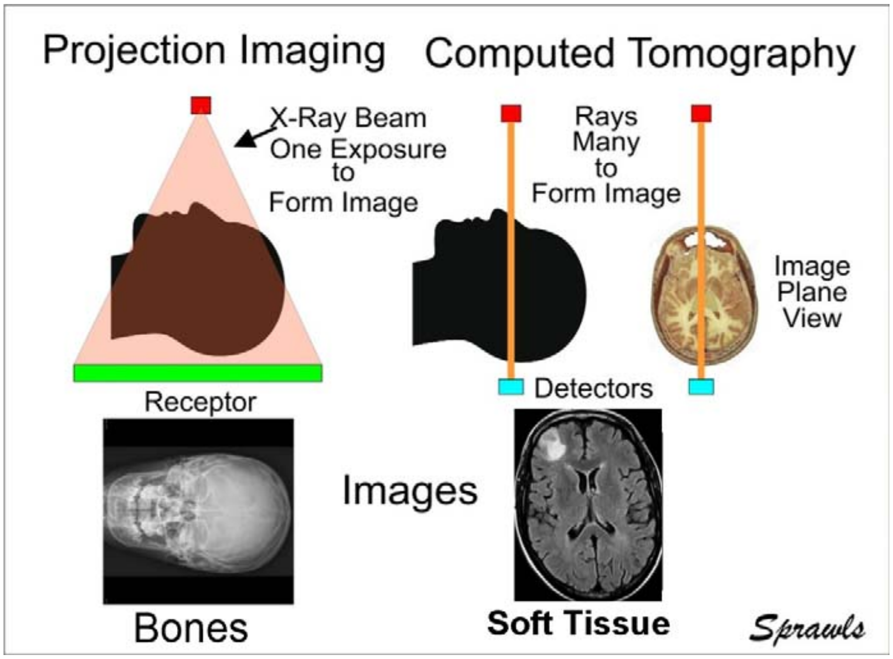


Contrast sensitivity is a characteristic of an imaging procedure that is controlled by a combination of other factors, some the design of the equipment, others were the adjustable factors by the operator setting up the “technique” or “protocol” for the procedure. The general concept is illustrated here. The visibility is extended to the objects with lower physical contrast with increased contrast sensitivity of the imaging procedure.

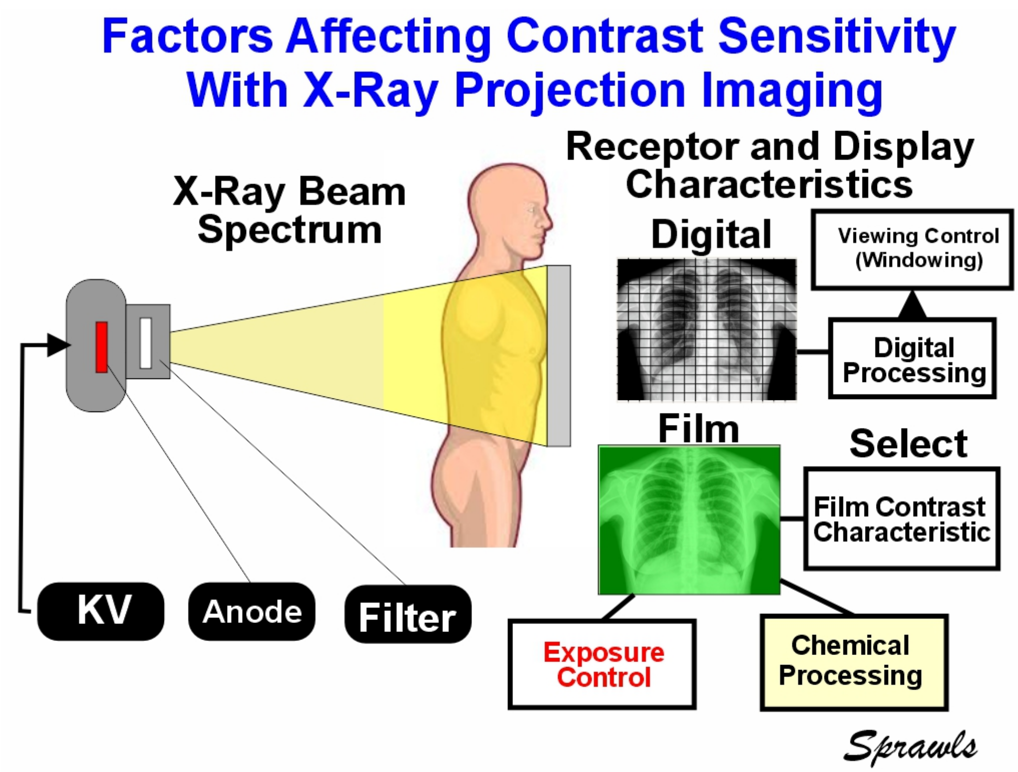
The contrast sensitivity with X-ray imaging depends on the characteristics of the imaging procedures with a major difference between the two viewing methods, projection imaging and computed tomography as illustrated here.

Projection imaging, first introduced and demonstrated by Roentgen, continues to be the fundamental principle of both radiograph and fluoroscopy as practiced today. Although many advances have been made, as described later, contrast sensitivity has generally been limited to imaging high-contrast bones, the chest, and contrast media, with one exception, mammography, as described later.

The invention and development of computed tomography (CT) revolutionized medical imaging by extending contrast sensitivity to include the soft tissues, especially those within the skull.



Contrast Sensitivity with Projection X-ray Imaging



A continuing effort beginning with Roentgen's introduction of X-ray imaging of the interior of the human body has been to expand the scope of *visibility* to include more objects and conditions, especially those that are of clinical significance, for example the early detection of cancer. This has occurred with inventions, discoveries, and developments addressing each of the image and imaging procedure characteristics that affect visibility. By far, the most significant is the *contrast sensitivity* of the imaging process. This is determined by a complex combination of many factors as illustrated here. These are in two categories, those associated with the X-ay beam and those associated with the receptor and display of an image.

The X-ray Beam Spectrum and Contrast Sensitivity

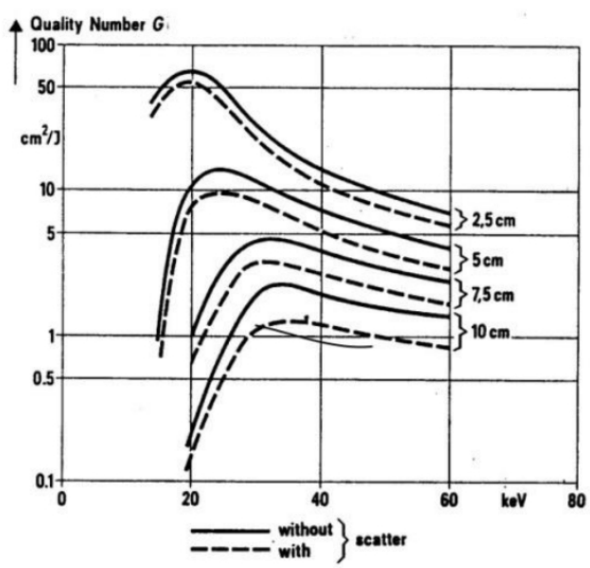
The physical contrast that is visualized with all forms of X-ray imaging is the difference in X-ray attenuation between the various tissues or other materials in the body, As observed previously, this depends on physical density and atomic number (Z). The effect of Z on visible contrast is heavily dependent on the X-ray spectrum, being most effective with the spectrum photon energies just above the K-edge energy of the tissue components where the photoelectric effect is most prominent. However, with higher photon energies where the Compton interaction is prominent, density differences between tissues is source of contrast.

For the relatively low atomic numbers (Z) of the components of the human body the x-ray attenuation decreases with increased photon energy within the x-ray spectrum. This produces two generally conflicting effects. The difference in attenuation, the source of physical contrast, decreases. However, the attenuation by the human body decreases which reduces the exposure or radiation dose to the patient required to deliver the necessary exposure to the receptor that will produce an appropriate image.

This has been the challenge throughout the history of x-ray imaging, providing an X-ray beam with a spectrum that balances the requirements for contrast sensitivity (visibility) and lower exposure to the patient. This is an optimized spectrum. For general x-ray imaging, both radiography and fluoroscopy, over the years tubes with tungsten anodes and added aluminum filtration were used. The KV was the adjustable factor that could be used for each patient procedure to optimize visibility with exposure to the patient.

Generally higher KV values (100 – 120kV) and sometimes additional filtration were used for imaging the chest because of the high physical contrast, density differences, within the chest. A KV value of around 70kV produced a spectrum with a peak or maximum intensity close to the K-edge energies of the contrast media, iodine, and barium. This would produce maximum contrast but sometimes not adequate penetration through the thicker body sections and higher KV values are used. For the thin extremities, especially hands, lower KV values are used than in addition to showing the bones provides some visibility of the soft tissues that can be of diagnostic value.

The breast which is composed only of soft tissues remained a challenge, and a method for visualizing the breast tissues was desperately needed to detect cancer, especially in the early stages when treatment can be most effective. This would require an X-ray beam spectrum with much lower energy than could be produced with the conventional radiographic systems. The specific challenge was to produce a spectrum that was optimized to balance the requirements for contrast and visibility along with minimizing radiation exposure to the patient. A major development was the research by Gajewski & Reiss and the publication of the results shown here.



$$\text{Quality Number } G = \frac{(\text{Contrast})^2}{\text{Radiation exposure } (\text{J/cm}^2)}$$

(Gajewski and Reiß, Der Radiologe Heft 10/74)

They conducted experiments with phantoms simulating breasts of different thicknesses measuring contrast of an embedded object and the exposure to the simulated breast. A quality number (G) was defined as the ratio of the square of the contrast to the radiation exposure. When the quality number is plotted in relation to X-ray photon energy as shown above two major facts are revealed.

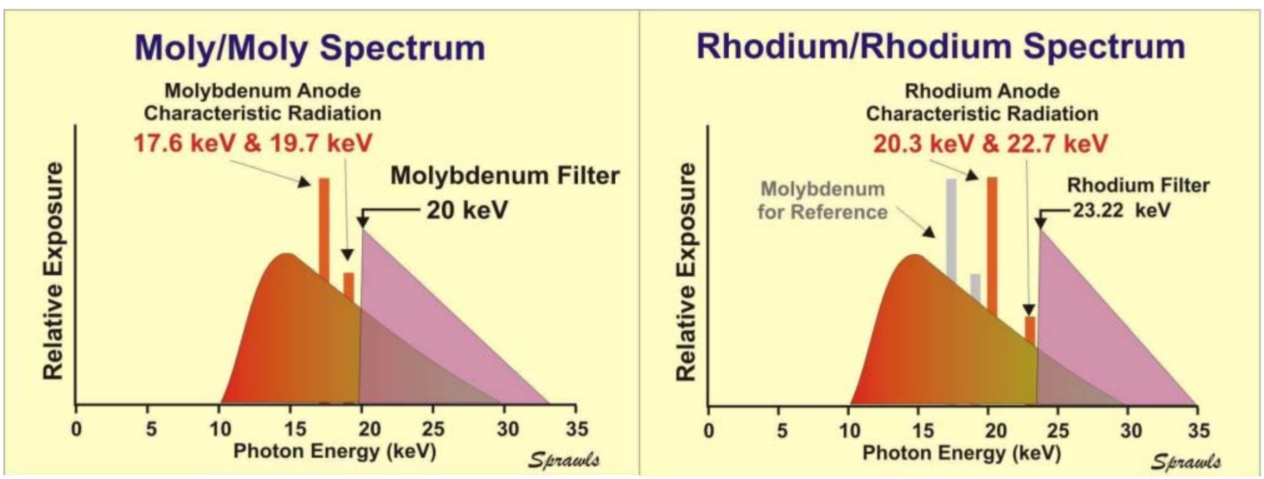
- For each specific breast thickness there is a photon energy that produces the maximum contrast (visibility) in relation to radiation exposure.
- With increasing breast thickness, the peak in quality number moves to a higher photon energy and the quality number representing the ratio of visibility to radiation exposure decreases.

This was to give direction for developing the technology that would produce optimized spectra to be the foundation of X-ray mammography for years to come. This, along with many other innovations is described in:

THE SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENTS IN MAMMOGRAPHY A CONTINUING QUEST FOR VISIBILITY
P. Sprawls. MEDICAL PHYSICS INTERNATIONAL Journal, vol.7, No.3, 2019
http://www.mpijournal.org/pdf/2019-SI-02/MPI-2019-SI-02-p141.pdf

The first was to modify existing X-ray tubes having tungsten anodes by replacing the glass windows and aluminum filters with lower atomic number beryllium so that the low energy photons would not be attenuated. The generators (electric power supplies) were modified to provide KV values in the 30 kV range…well below what is used in conventional radiography. The spectra produced with this technology provided the foundation for establishing mammography as a highly valuable imaging method for detecting and diagnosis cancer.

The bremsstrahlung spectrum produced with a tungsten anode, minimal filtration, and low KV produced good contrast but was somewhat broad and spread beyond the optimum energy to maximize contrast and visibility in relation to radiation exposure to a patient. The next major innovation was the development of X-ray tubes with anodes to produce characteristic radiation at the desired energy and filters with K-edge energies to attenuate the higher energy bremsstrahlung. The first was molybdenum for both anode and filter and later tubes with dual anode tracks to include rhodium and a rhodium filter. This provides several combinations of anodes and filters to produce spectra as shown here.



After considering the compressed thickness and density of a patient's breast the technologist could select from the available anode and filter combinations and a KV value, generally in the range of 26kV-40kV, that would produce an optimized X-ray beam spectrum for extending visibility to more of the human body and signs of a major and deadly disease, cancer. With the development of low photon energy spectra as applied in mammography visibility was extended to the differences, or contrast, among the soft tissues in the body.

The challenge of the Brain

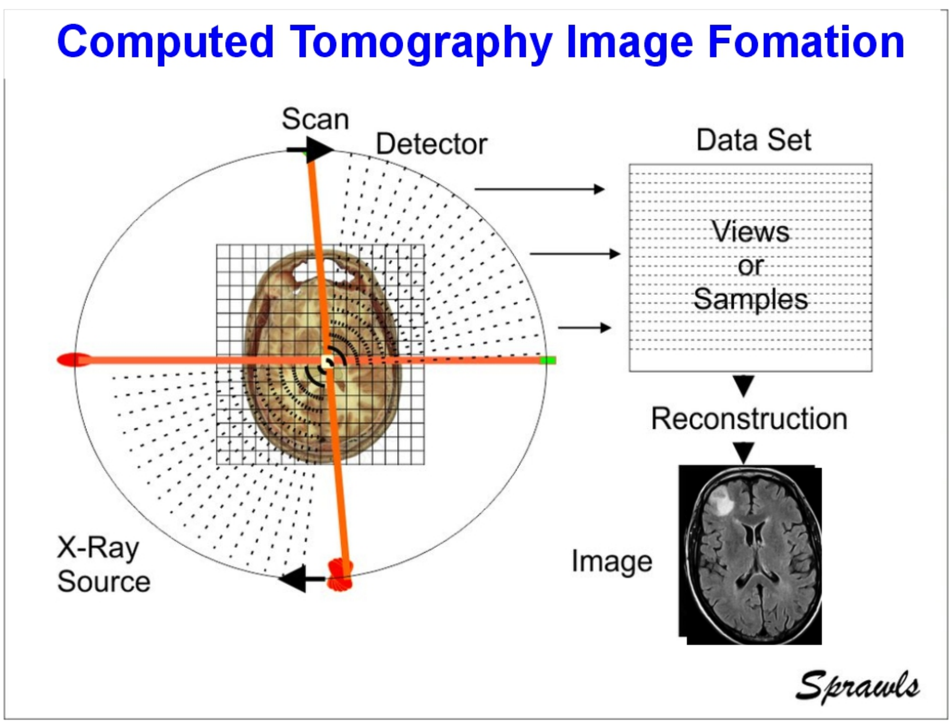
One organ, the brain, remained a challenge because it is enclosed in the dense skull. The low photon energy spectra that can produce contrast among the soft tissues cannot penetrate the head. Radiography of the head was a valuable procedure for visualizing the skull, especially to diagnose malformations and fractures, but the soft tissues of the brain remain invisible.

What was needed was an imaging method with an X-ray beam that could penetrate the skull and visualize the physical contrast (density) of the brain's soft tissues. This was not possible with conventional radiography using an X-ray beam projected through the body and forming "shadow" images.

Godfrey Hounsfield was an engineer on the staff of EMI in England and worked on many projects during his career. Although it was not one of his major projects he had an interest in computerized imaging, pattern recognition, etc. The legend is he was on vacation along with a physician and they were having discussions about imaging, assumed from their different perspectives. The physician explained that a major problem was being able to image the brain because it was enclosed in the dense skull. This motivated Hounsfield to develop a solution. That was to extend his research and to develop the new technology, computed tomography (CT). The details of this development and continuing evolution over the years is presented here:

THE MANY STEPS AND EVOLUTION IN THE DEVELOPMENT OF COMPUTED TOMOGRAPHY TECHNOLOGY AND IMAGING METHODS, THE QUEST FOR ENHANCED VISIBILITY The First Fifty Years
P. Sprawls. MEDICAL PHYSICS INTERNATIONAL Journal, vol.7, No.3, 2019
http://www.mpijournal.org/pdf/2020-SI-04/MPI-2020-SI-04-p351.pdf

The specific contribution of computed tomography (CT) was to provide adequate contrast sensitivity for visualizing the soft tissues of the brain within the dense skull. The details are described in the publication referenced above but are illustrated and summarized here.



Computed tomography, which provided high contrast sensitivity, especially for imaging the brain, also introduced a revolutionary approach to medical imaging that was to be followed by future imaging modalities, MRI, and SPECT. That was a method producing images of slices of the body (tomograms) that had consisted of two distinct phases. Image formation is in two phases. The first phase, generally referred to as *scanning* passes a narrow x-ray beam through the body from many directions that measures the total attenuation along each path. The second phase, designated as *image reconstruction*, uses a mathematical transform (the actual foundation of computed tomography) that transforms the attenuation values for each path through the body into attenuation values for individual voxels in a matrix forming a *digital image*.

The high contrast sensitivity is possible because the attenuation values (coefficients) for the individual voxels (to be displayed as image pixels) are sufficiently different that can be displayed in an image with different brightnesses, or *visual contrast* using the processing illustrated here as published by Hounsfield.

VOL. 46, No. 552

G. N. Hounsfield

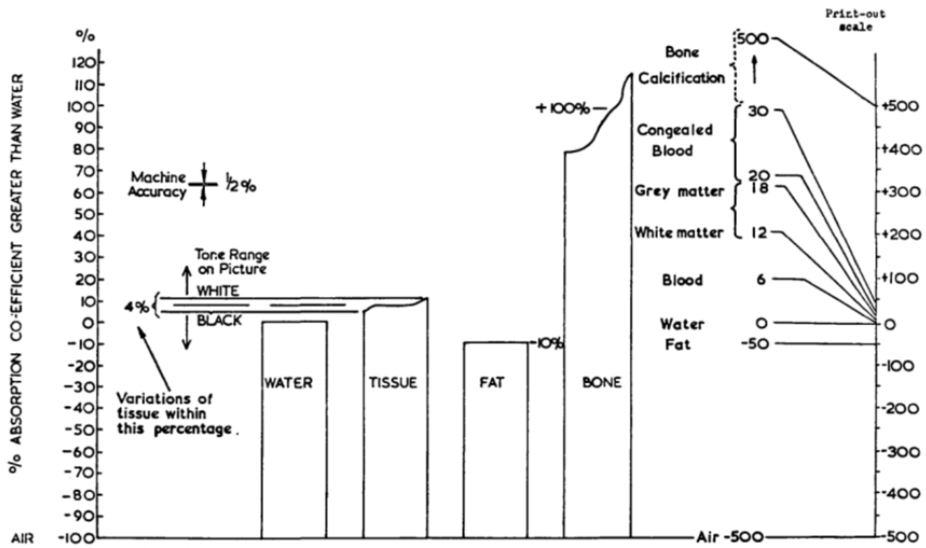
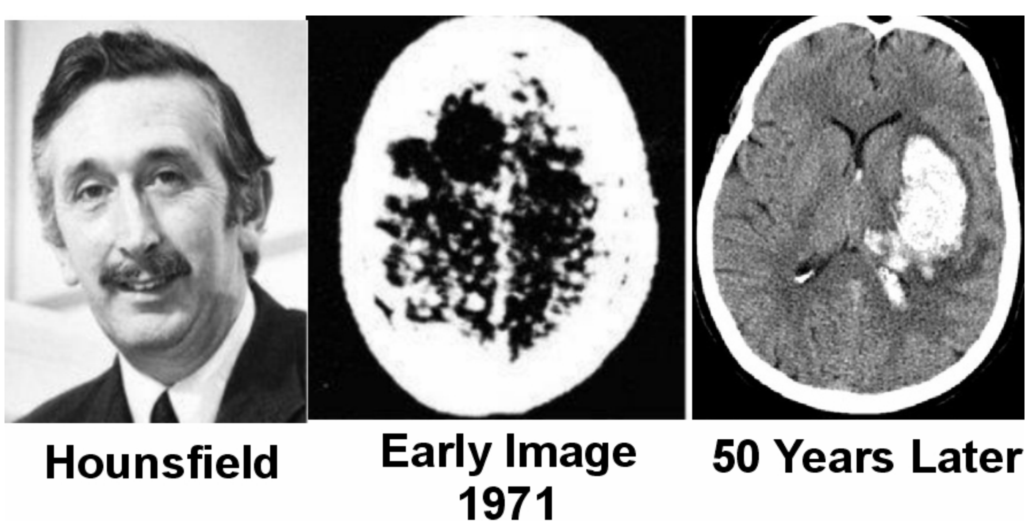


FIG. 9.

Illustration of machine sensitivity. The scale on the right is an arbitrary scale used on the print-out and is related to water = 0, air = 500 units. It can be seen that most materials to be detected fall within 20 units above zero and can be covered by the adjustable 4 per cent "window".

Hounsfield developed a scale of relative attenuation values in relationship to water with a value of zero. Tissues that were denser than water had positive values and those less dense, fat for example, had negative values. The scale extended from -500 for air to +500 for bone. This was later to be designated as the Hounsfield scale and numbers.

The significance was the numbers for the tissues were sufficiently different to provide visible contrast when printed out or displayed in an image. This was achieved using a "window" when viewing that selected a small range of numbers (for example, representing the soft tissues) and displayed over a wide range of brightness levels (from black to white) in the viewed image.

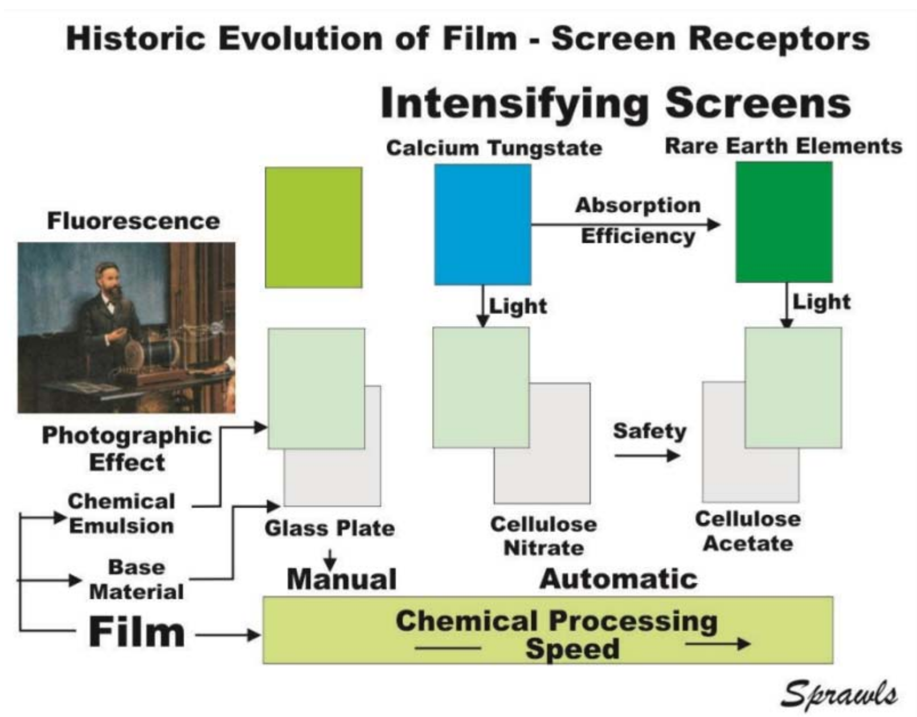


The historical significance of one the early CT images shown here stands along with the X-ray image of a human hand demonstrated and presented by Roentgen in 1896. Visibility into the human body had now been extended to include the brain enclosed within the skull. The significant factor was that the signs of a disease, a tumor, were visible. The general quality was very inferior compared to future images, but it did demonstrate a contrast sensitivity providing visualization of brain tissues and a disease for the first time in history. This was to be followed by many developments in the CT technology and methods addressing other image characteristics to expand visibility to include many conditions within the brain and to become a major diagnostic method in the field of neurology and the expanding specialization of neuroradiology.

Image Receptor Characteristics and Contrast Sensitivity.
As indicated in a previous illustration there are several characteristics of the receptors in X-ray imaging that influence contrast sensitivity and visibility. For around a century following Roentgen's introduction photographic type film was the component of the receptor for recording and displaying an image. The film could be exposed directly by the X-ray beam or most often, by light from a fluorescent intensifying screen that was in contact with the film. Because film is much more sensitive to light than X-radiation images could be made with much less radiation to a patient by using intensifying screens.

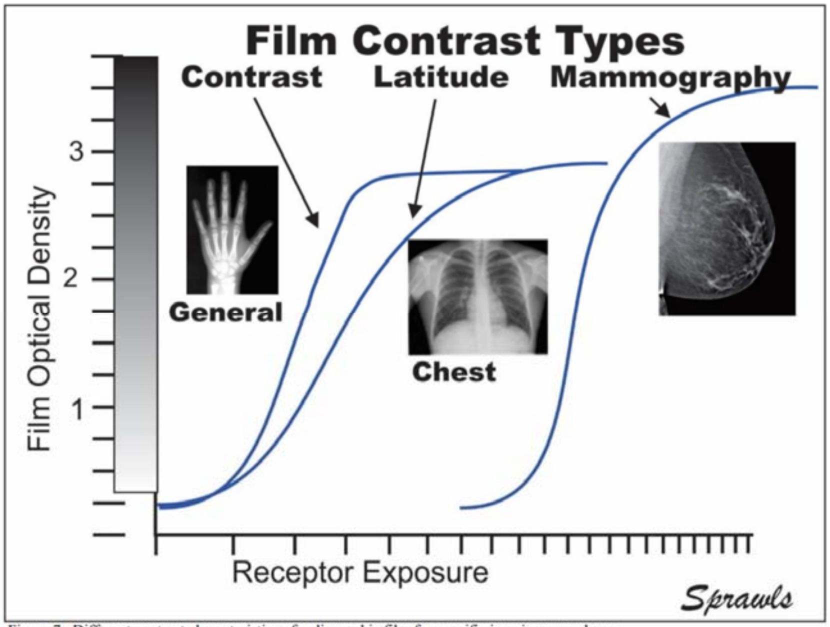
Characteristics of both the film and the intensifying screens had significant effects on visibility but it was characteristics of the film that affected contrast sensitivity. During the first century both film and intensifying screens benefited from a series of innovations and developments to increase visibility and minimize the radiation exposure to the patient and is described here.

FILM-SCREEN RADIOGRAPHY RECEPTOR DEVELOPMENT A HISTORICAL PERSPECTIVE
P. Sprawls. MEDICAL PHYSICS INTERNATIONAL Journal, vol.7, No.3, 2019
http://www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01-p56.pdf

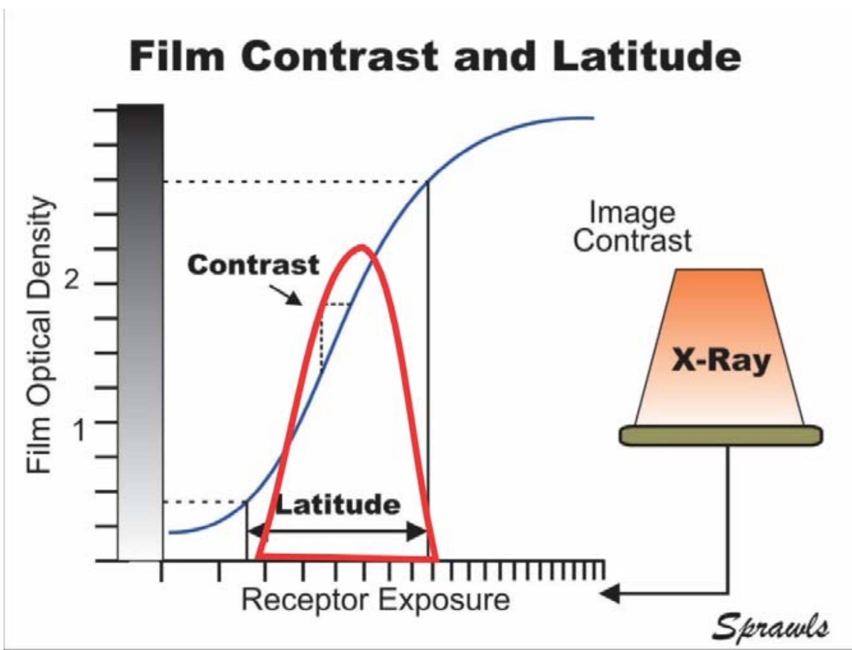


A major effort during his time was to develop film with contrast characteristics that would provide the best visibility for the different anatomical regions, the chest being very different from the breast.

The contrast characteristic of a film can be described with the contrast, or H & D graphs as shown here.



These curves show the relationship between film density (visible brightness) and exposure to the film. It is the slope of the curve at every point that represents contrast.



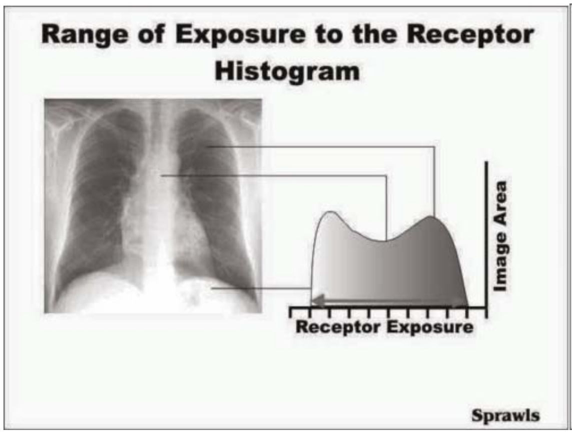
As illustrated here, there is a limited range of exposure that is within the slope of the characteristic curve that will produce image contrast. This is within the latitude of the film.

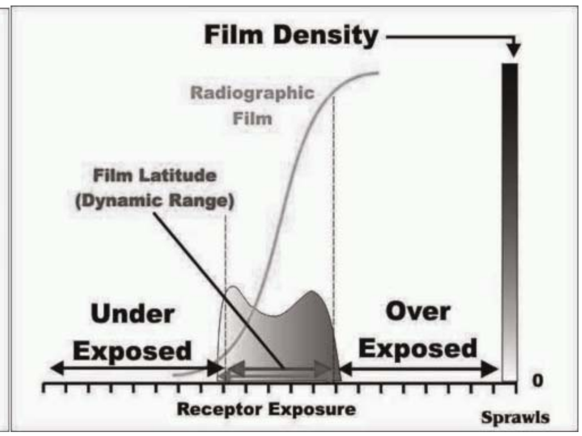
Selecting the appropriate film for a specific procedure was the first step but the next two were the critical ones for obtaining maximum contrast and visibility.

Maximum contrast requires the exposure reaching the receptor to be within the latitude range of the film…not always easy to do. The exposure factors (KV, MAS) for the procedure must be adjusted in relation to the size and anatomical location of the patient. If an automatic exposure control (AEC) is used it must be properly calibrated, adjusted, and positioned. Variations in the chemical processing can both reduce the contrast and shift the latitude range contributing to errors in exposure.

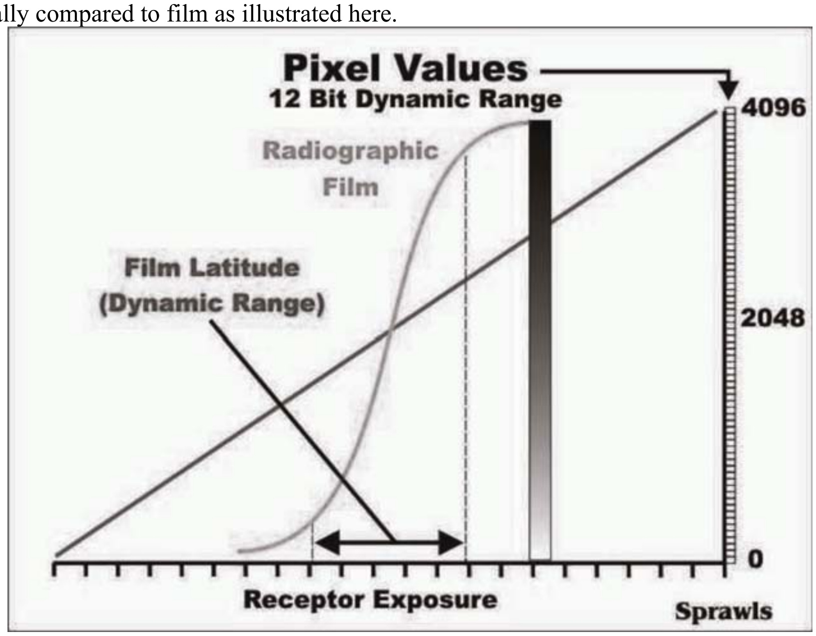
While film was a valuable receptor and display medium for many years its limitations for providing maximum contrast and visibility as described here and along with many other factors including cost, difficulties with the chemical processing, storage and retrieval, and limited control with viewing, were reasons for it to be replace with digital imaging as that technology was developed.

Digital radiography provides many advantages over film but our interest here is specifically in its contribution to increasing visibility throughout the body. As illustrated above with film radiography, the X-ray exposure penetrating the patient's body must fit within a relatively narrow range to produce maximum contrast and visibility. That is within the latitude of the film. This was often a challenge because of errors in adjusting the exposure and the range of exposure from the body. That can be expressed as a histogram and compared to the range of film exposure that can produce adequate contrast as illustrated here.

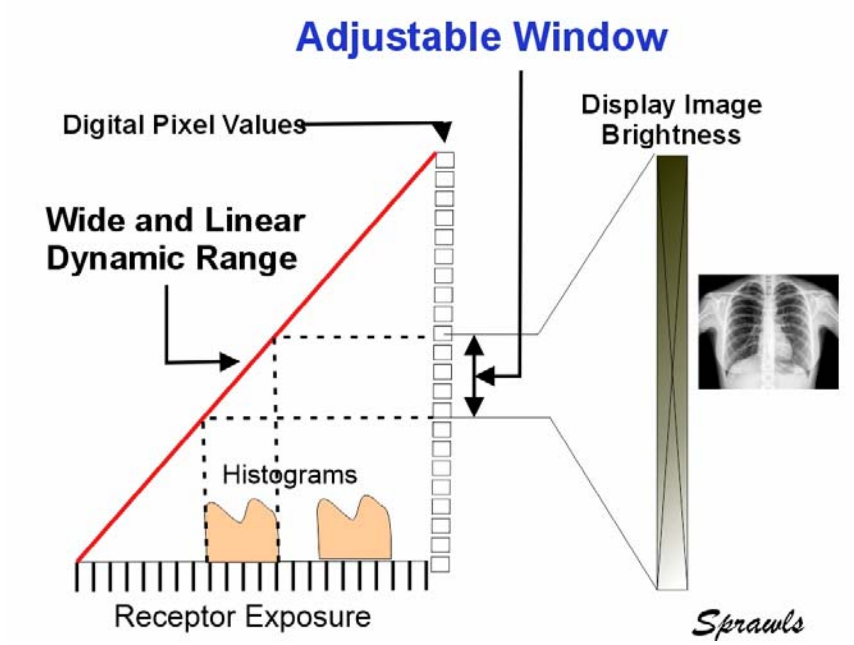




Digital radiography uses several different technologies for the receptor, but a common characteristic is they have a wide *dynamic range*, especially compared to film as illustrated here.



A digital image is recorded as a matrix of pixels with each pixel having a numerical value that has a long and linear relationship to the X-ray exposure to the pixel area. This is very different from images recorded on film that has a short and curved relationship between exposure and displayed film optical density or brightness.



With respect to contrast and visibility the great contribution of digital imaging was the ability to record the image data with a wide dynamic range so that no data was lost, as was possible with film, and then select the range of the recorded data, the histogram, and display it over the full brightness range using the window control.

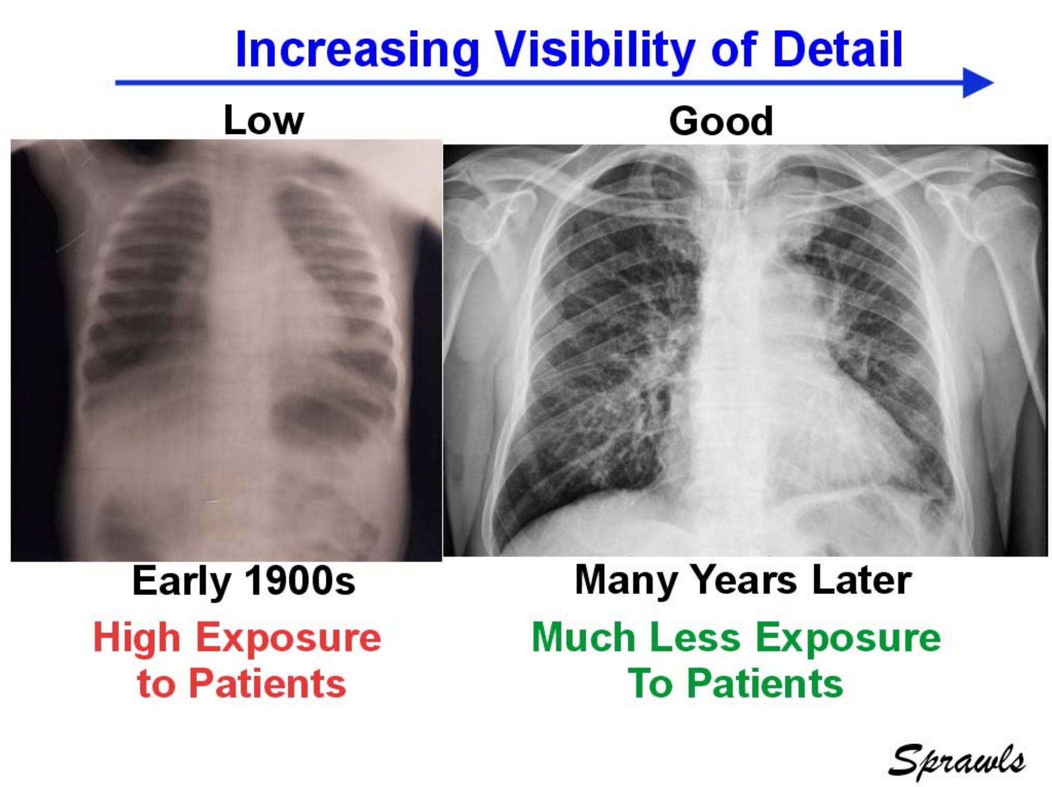
This capability was not only used in digital radiography, but also the other modalities that produced digital images, CT, MRI, and SPECT. It was a major development extending the range of contrast sensitivity throughout the human body.

Contrast Sensitivity in Summary

The fundamental requirement for X-ray imaging is the ability to "see" or visualize structures and conditions within the human body. These vary in several characteristics including their *physical contrast.* Only the large bones were visible in Roentgen's first images because they were dense, thick, and composed of calcium. A series of investigations and developments addressed the X-ray beam spectrum and optimizing it for visibility in different anatomical regions, ranging from the high-contrast chest to the challenging breast with very low physical contrast between the soft tissues. Receptors with film were used for almost a century. Even with some improvements in contrast characteristics over the years the challenges of limited latitude (dynamic range), obtaining correct exposure, and requiring chemical processing with its cost and variability established it for replacement with digital when that technology was developed. Digital imaging provides a wide and linear dynamic range with the ability to window and enhance contrast for selected tissues and anatomical regions. This was the function that enabled CT to provide very high contrast sensitivity and expand visibility in the body, especially to the brain.

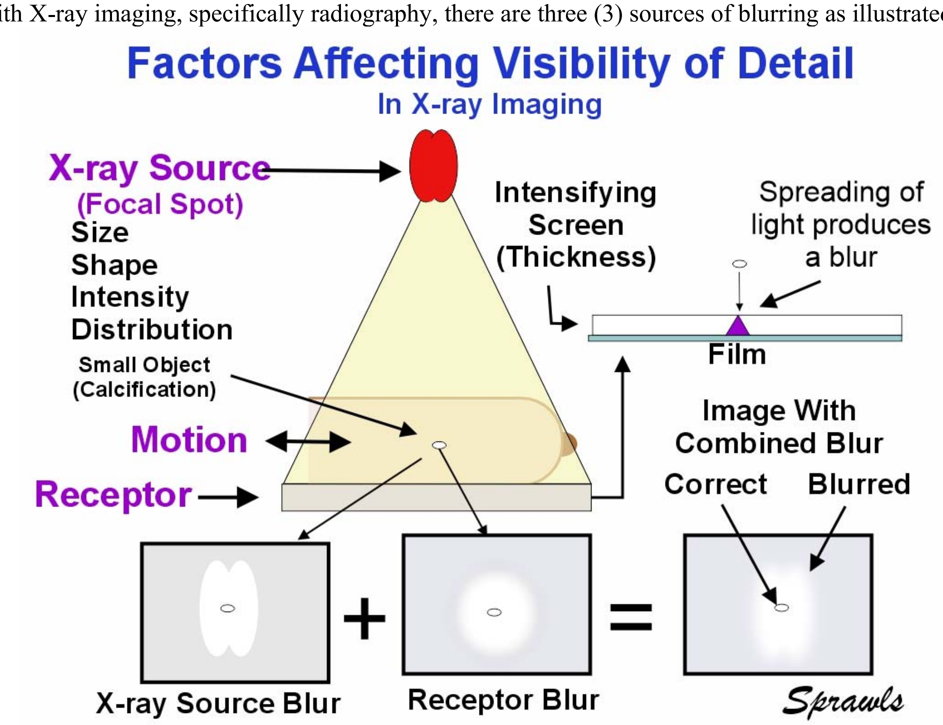
VI. VISIBILITY OF DETAIL

Following the introduction of X-ray imaging by Roentgen it was the visibility of the physical contrast between the different tissues and other materials in the body that revolutionized the practice of medicine. As we have just read and seen, this was followed by many years of research and development to extend visibility to include items with low physical contrast, especially female breast, and the brain within the skull. There were many items of clinical significance that remained invisible because of their size, they were too small to see and generally designated as *anatomical detail***.** Along with efforts to increase contrast sensitivity over the years there was also attention to increasing *visibility of detail* as illustrated here.



As new technologies and methods were developed a major consideration was reducing the radiation exposure to patients and optimizing it with the requirements for visibility.

With all imaging methods, including human vision, it is the blurring within the process that limits visibility of detail, the small things. With X-ray imaging, specifically radiography, there are three (3) sources of blurring as illustrated here,



For more than a Century many inventions and developments have contributed to increased visibility of detail in X-ray images. These have concentrated on the three (3) sources of blurring: the x-ray source, the design of the receptor, and motion of the patient during the exposure to form the image.

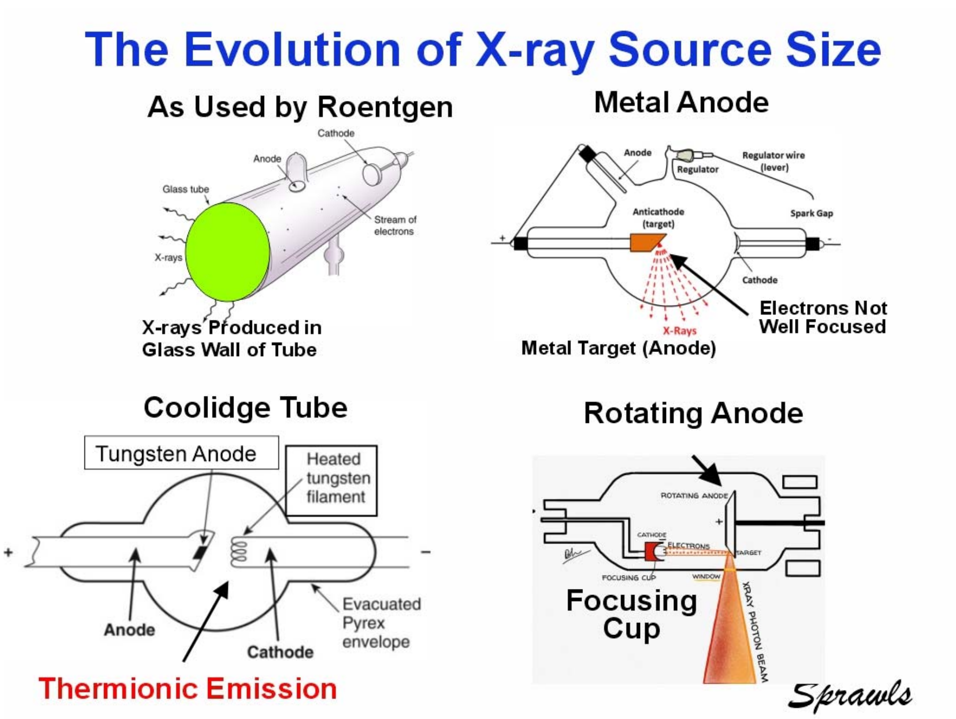
Blurring by the X-ray Source

When images are formed by projecting an X-ray beam through the human body the "sharpness" of the shadow image is affected by the size of the X-ray source in combination with the geometry of the procedure, that is the distances between the source, patient. and receptor. It is the blurring, sometimes perceived and described as "un-sharpness" that reduces the visibility of small objects, that is visibility of detail. For a specific geometry the blurring and visibility of detail is determined by the characteristics of the X-ray source: size, shape, and the distribution of radiation intensity over the area of the source.

A continuing effort following the introduction of X-ray imaging by Roentgen has been to reduce the size of the radiation source, that were to become known as *focal spots.* That along with the story of many other innovations in X-ray tubes is provided here.

X-RAY TUBES DEVELOPMENT - IOMP HISTORY OF MEDICAL PHYSICS
Rolf Behling, Philips Healthcare Roentgenstrasse 24, 22335 Hamburg, German
MEDICAL PHYSICS INTERNATIONAL Journal, Special Issue, History of Medical Physics 1, 2018 8
http://www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01-p08.pdf

Four phases of that development related to source or focal spot size are shown here.



Roentgen's Tube

The tube used by Roentgen at the time of the discovery and early experiments was not designed to be an X-ray tube, but for other demonstrations and experiments. When energized with a high voltage, electrons from the ionized low-pressure gas were accelerated toward the end of the tube and striking the glass wall that became the radiation source. It was large in area but not an efficient X-ray source.

Metal Anodes

Roentgen quickly discovered that metal was much better than glass for producing X-radiation and had tubes prepared with several types of metal anodes as the source. For at least the next 20 years tubes with metal anodes were manufactured and used around the world to establish X-ray imaging as a valuable medical procedure. These tubes contained a low-pressure gas that was ionized to produce the electrons that struck the anode to produce the radiation. They were not well focused, and the size of the source was large, compared to later tubes. The quantity of electrons from the ionized gas was very limited and the low X-ray production required long exposure times to image a patient.

The Cooledge Tube

William Coolidge was a scientist and engineer who in 1905 joined the General Electric Research Laboratories with his first work to improve lightbulb filaments. His research resulted in the development of so-called "ductile tungsten" that was to become the filaments for lightbulbs for many years.

He recognized tungsten had several properties that made it valuable for use in X-ray tubes. Both as an anode and a cathode that could be heated to a very high temperature where it would emit electrons, thermionic emission. This made the cathode the actual source of electrons rather than the ionized gas in the tube. The advantage was dramatically- higher tube currents (MA) and X-ray production. The tube current (MA) could be regulated by adjusting the temperature of the cathode filament. The other major advantage was with the addition of a focusing cup to the cathode the electron beam could be focused to produce small focal spots as the X-ray source.

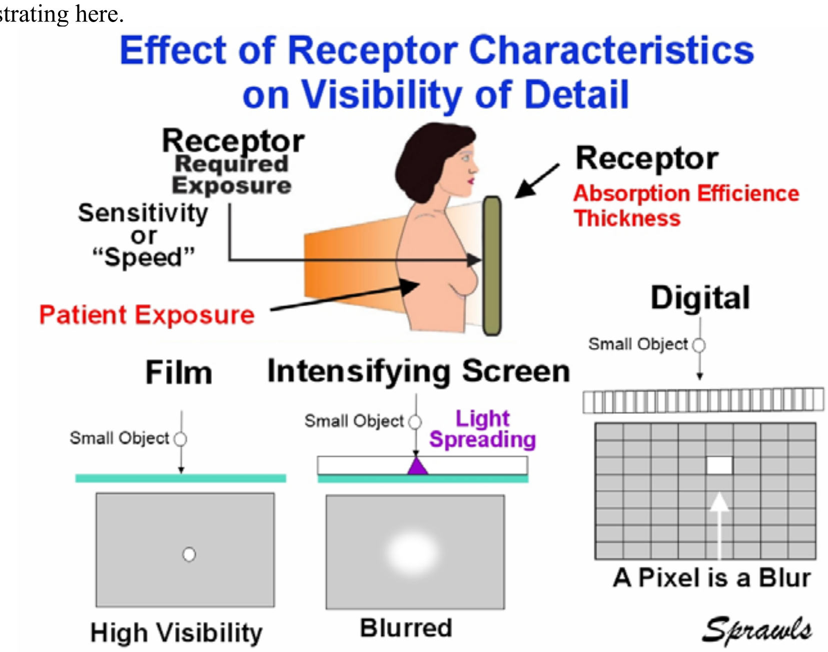
Rotating Anodes

The availability of small focal spots, in the order of a millimeter, was a major advantage extending visibility of detail but created another problem. Most of the energy of the electrons bombarding the anode is converted to heat. When this heat is concentrated in small areas on the anode, melting and damage can occur. The introduction of rotating anodes provided for spreading the heat over a large area and permitted tubes to be operated with much higher currents and X-ray output. The design of tubes with smaller anode angles permitted even smaller effective (projected) focal spot sizes in relation to the actual area where the heat is produced.

Effects of Receptors on Visibility of Detail

The design of the receptor that "receives" the X-ray beam after it has passed through the patient's body and transforms it into a visible image has a significant effect on the *visibility* of detail. This is because of the blurring introduced into the image.

The ongoing research and development of receptors for X-ray imaging, specifically radiography, includes three (3) major types, or phases illustrating here.



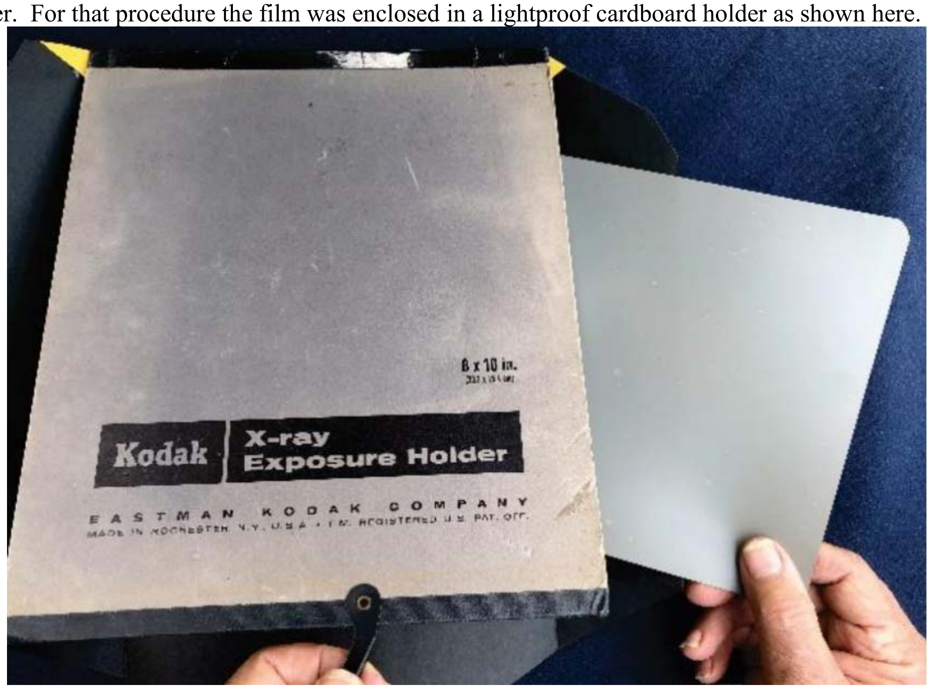
First introduced by Roentgen was photographic type film that he had discovered was sensitive to X-radiation and could be used to record images. The next and long-lasting phase was using fluorescent intensifying screens to first absorb the X-radiation and use the light to expose the film. The final and continuing phase is using digital technology. Each of these technologies have design characteristics that affect and generally limit visibility of detail.

A highly significant and related factor is the quantity of radiation required to form an image and that also affects the radiation delivered to the patient. The selection of a receptor for a specific patient procedure often requires a decision on balancing the need for visibility of detail while minimizing the exposure to the patient.

The first function of a receptor is to *absorb* the X-radiation and then convert it into a visible image, often requiring several steps. The absorption by a specific receptor is determined by absorption efficiency of the material and the thickness of the receptor. It is the thickness of the absorbing receptor material that is critical to visibility of detail because blurring can occur within that thickness,

Film as a Receptor

Photographic type film was the first receptor discovered and used by Roentgen, and it was generally available. The X-radiation was absorbed in the very thin emulsion layer and produced excellent visibility of detail. However, the thin emulsion layer was not an effective radiation absorber and required very high exposures to produce an image. With no alternative at that time, film continued to be developed and used as the receptor. This included the emulsion coated on large glass plates and used for large anatomical regions, especially the chest. Even after intensifying screens were developed and became the standard for general radiography, Film directly exposed by the X-radiation continued to be used for procedures requiring high visibility of detail, especially mammography for visualizing very small calcifications, a significant sign of early breast cancer. For that procedure the film was enclosed in a lightproof cardboard holder as shown here.

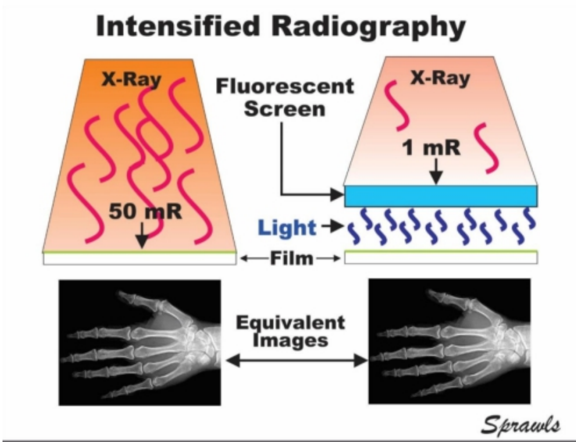


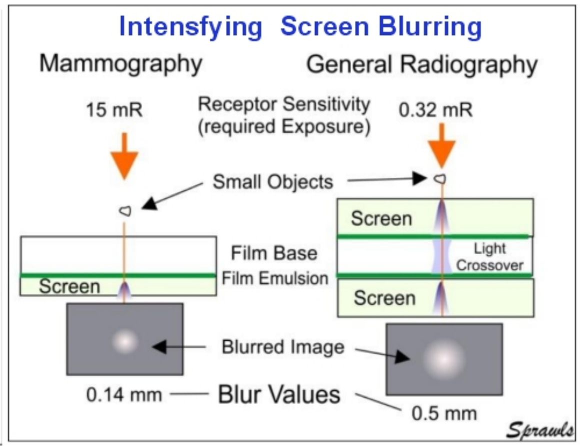
Excellent visibility of detail, the calcifications, but with a concerning high exposure to the patient.

Intensifying Screens and Reduced Exposure

One of Roentgen's first discoveries was that the *New Kind of Radiation* interacted with fluorescent materials and produced visible light. This is how he viewed the first image, and fluorescent screens quickly became the receptors for fluoroscopy procedures and for many years to come.

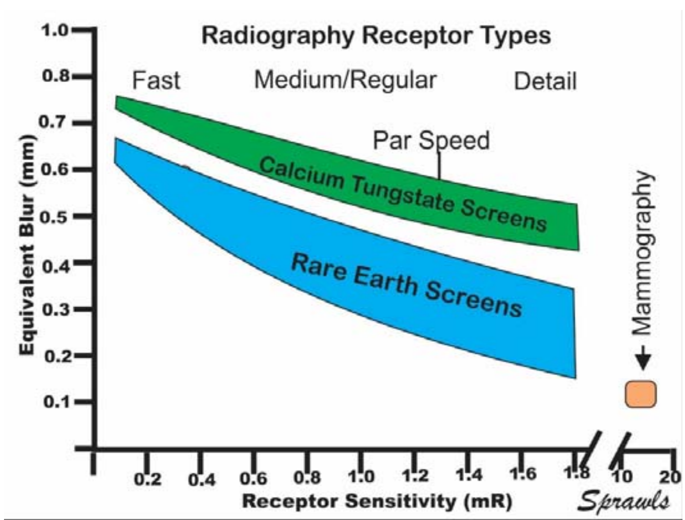
Thomas Edison, a prolific inventor, discovered that Calcium Tungstate was a fluorescent material apparently interested in it a source of light. However, it was not until around the 1910s that many of the technical issues were resolved and practical intensifying screens for clinical imaging became available. The advantages and disadvantages of intensifying screen for X-ray imaging are illustrated here.





When a fluorescent screen is placed in contact with a film it creates an X-ray image receptor that requires much less X-ray exposure to form an image compared to exposing the film directly. This is because the thicker layer of material, like Calcium Tungstate, is a much more efficient X-ray absorber than the thin silver halide emulsion layer of the film. This is sometimes expressed as the intensification factor and an example value of 50 is shown. While the use of intensifying screens provides a dramatic reduction in exposure to patients, the trade-off is a reduction in visibility of detail caused by the spreading of the fluorescent light within the thickness of the intensifying screen as illustrated on the right. The amount of blurring depends on several factors, the most significant being the thickness of the screens. That is the problem, thicker screens are needed for increased X-ray absorption and reduced exposure, but thicker screens produce more blurring. Generally, when intensifying screens were used in a clinical facility there was diffident types to select from depending on the need for visibility of detail. The two major types are illustrated. For mammography that requires high visibility of detail to visualize very small calcifications a single thin intensifying screen is used, for general radiography, two screens to increase X-ray absorption were placed on both sides of film with emulsion on each side as illustrate.

Around the 1970s several so-called "rare-earth" fluorescent materials became available and began to replace Calcium Tungstate in a next generation of intensifying screens, The advantage was a higher X-ray absorption because their atomic number (Z) values positioned their K-edges near the peak intensity of the typical X-ray beam spectrum. The general choices that existed are shown here.

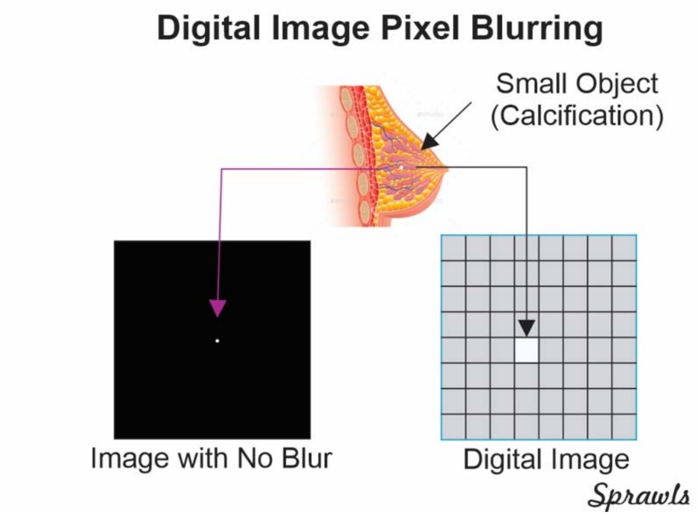


Generally, there were four (4) types of receptors that could be selected from, three (3) for general radiography and mammography that were very different from the others because of the need for high visibility of detail. The physical difference among the types was the thickness of the intensifying screens. The Medium/Regular type was used for many procedures, Detail used for imaging the bones in the extremities, and the Fast to minimize exposure and perhaps for large patients that were difficult to penetrate with the X-ray beam.

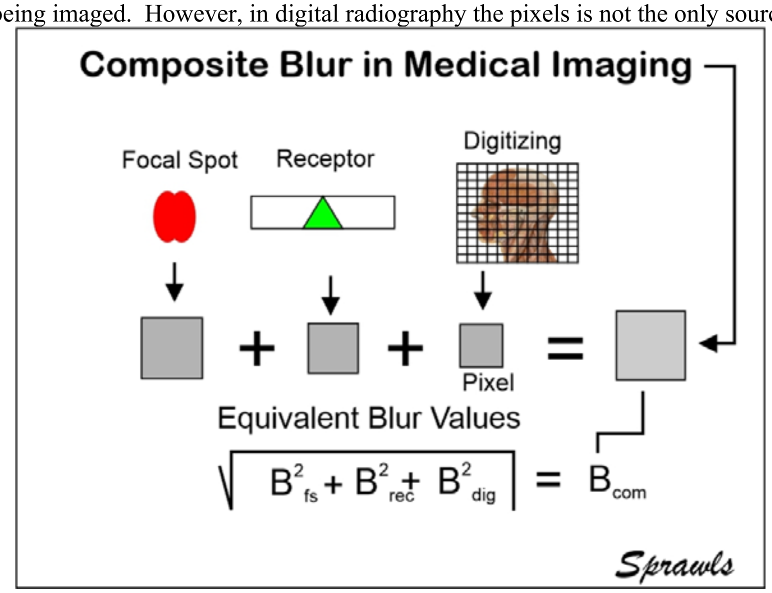
More details on the developments and evolution of intensifying screens is in the previously cited reference and can be viewed here: http://www.mpijournal.org/pdf/2018-SI-01/MPI-2018-SI-01-p56.pdf .

And Then There Was Digital

As computers and digital technology, especially for imaging, continued to develop it offered many advantages over film-based radiography. However, there was one concern. Digitizing an image could potentially reduce *visibility of detail*. Here our interest is only on the blurring effect of digitizing an image, not other details of the digitizing process,



In a digital image the individual pixels are the smallest thing displayed. For a small object, like the calcification shown here, it will be displayed as a pixel. In effect, a *pixel is a blur*. To maintain visibility of detail an image pixel needs to be smaller than the objects being imaged. However, in digital radiography the pixels is not the only source of blurring.

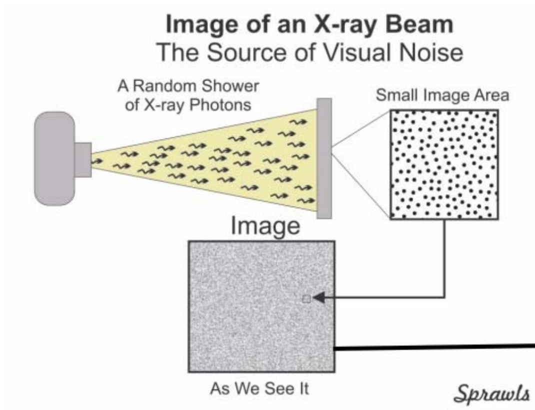


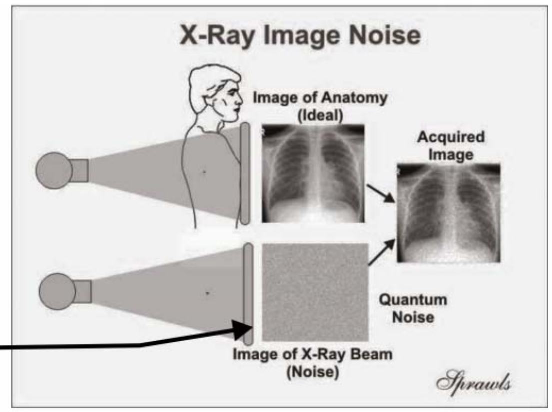
In digital radiography the pixel size must be considered along with the other sources of blurring, that is the focal spot and receptor layer that absorbs the X-radiation. An optimized design taking into consideration all factors would have a pixel size approximately the same as the blur from the other sources.

VII. Visual noise

After the discovery, Roentgen's extensive research documenting the many characteristics of the new radiation did not include the quantum structure consisting of individual photons. This is a highly significant characteristic because it is the major source of visual noise that can limit visibility in X-ray images. We can assume Roentgen did not see and discover this because he was using very high exposures to his receptors which minimizes noise.

With X-ray imaging the so-called quantum noise is an image of the X-ray beam that is added to the image of the patient as illustrated here.

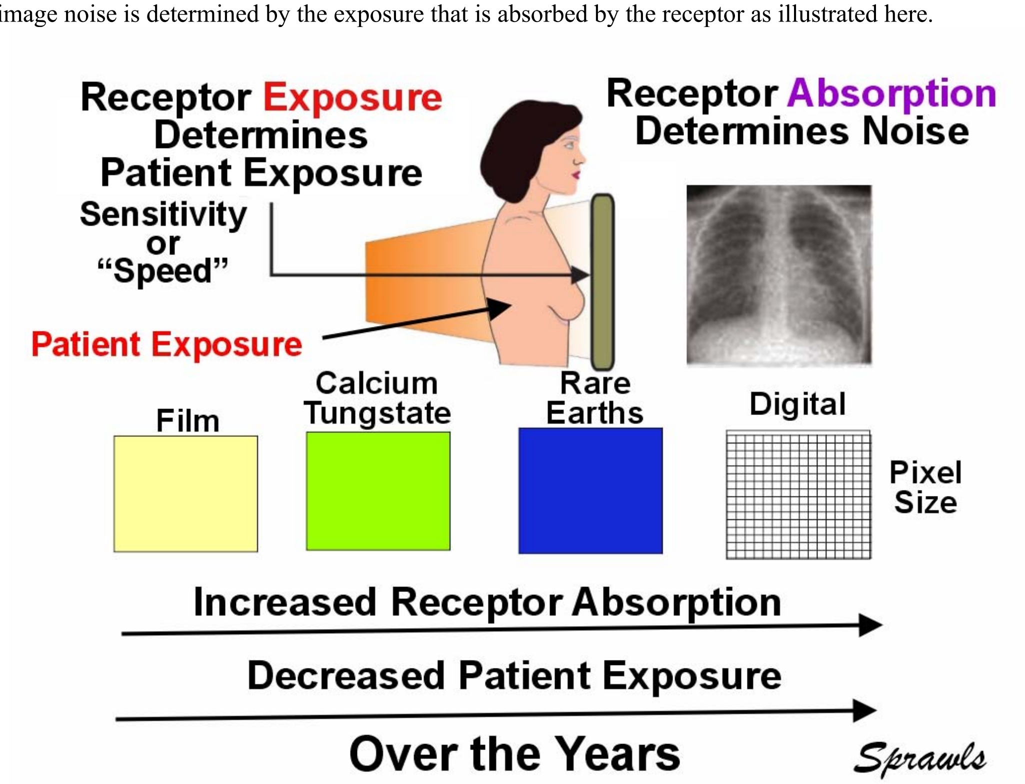




The clinical effect of visual noise is that it reduces the visibility of low-contrast objects in an image. This also includes small objects, like calcifications, because they are often with low contrast.

A continuing challenge throughout the history of X-ray imaging has, and continues to be, reducing the effects of noise on the visibility of the patient's body. As we recall, the visual noise is caused by the random statistical variation in the number of captured photons in small "sample" areas of the image. In digital radiography these are the image *pixels* and the *voxels* in CT. The noise, sometimes expressed as the standard deviation (SD) of the statistical variation among the pixels or voxels is inversely related to the exposure *captured* by the image receptor. For virtually all X-ray image receptors only a fraction of the exposure to the receptor is absorbed or captured and contributed to the formation of an image.

In X-ray imaging procedures the exposure to the patient is related to the required exposure to the receptor to produce an image. The image noise is determined by the exposure that is absorbed by the receptor as illustrated here.



Throughout the history of X-ray imaging research and development of new technology and methods have had two (2) major, and often conflicting objectives, increasing *visibility* and reducing radiation *exposure* to patients. This is often a factor in adjusting contrast sensitivity and visibility of detail but is especially significant in respect to visual noise.

The underlying factor is that X-ray image receptors do not absorb all the radiation they are exposed to. The exposure to a patient is related to the *exposure* to the receptor surface, the noise is related to the *absorbed* radiation, which is always less than the total exposure to the receptor.

Throughout the use of X-ray imaging there have been four (4) distinct phases relating to the absorption in the receptor and related patient exposure.

Film, the first receptor was a thin layer of photographic crystals and a very low X-ray absorption, this required very high X-ray exposures to produce the necessary image contrast. Because of the high exposure, quantum noise was not significant but noise from the grainy (crystals) structure of the film was.

Calcium Tungstate intensifying screens was the first major development reducing exposure to a patient. With this significant reduction in exposure noise could be seen in images. As described previously, screens were provided in three (3) types that varied in thickness to give a choice between visibility of detail and exposure to a patient. They all required about the same absorbed radiation to produce an image, and generally similar noise, but the thinner so-called "Detail" screens a higher receptor entrance and patient exposure.

Rare Earth intensifying screens were a revolutionary development because compared to Calcium Tungstate, they had higher *absorption* rates. A screen that could provide an image with the same visibility of detail and noise required lower entrance exposure and reduced patient exposure.

Digital receptors use a variety of different technologies and methods for producing images. In general, the materials used had reasonably good absorption characteristics, but another factor had to be considered, that was the size of the image pixels. Each pixel is a discreet sample, and it is the number of photons captured in each sample that determines the noise. Reducing pixel size to increase visibility of detail increases the noise because the number of photons captured is reduced.

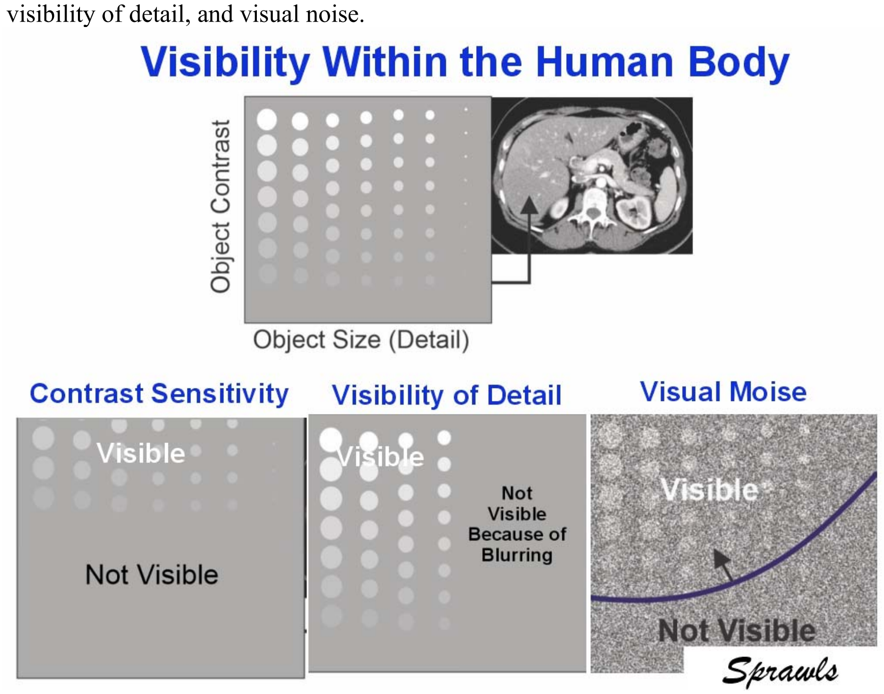
In all methods of digital imaging, radiography, CT, MRI, etc. this compromise between visibility of detail and visual noise must be considered when selecting pixel and voxel sizes for specific procedures.

An advantage with digital images is the possibility of mathematical processing to reduce the visible noise and is included in medical imaging systems.

Visual noise continues to be a factor to be considered in medical images but has been reduced over the years with advances in technology.

VIII. Overview and Conclusions

The discovery and extensive research by Prof. Roentgen on the characteristics and properties of "A New Kind of Radiation" quickly extended human vision into the human body and revolutionized the practice of medicine. From this beginning, many physicists, engineers, and medical doctors have collaborated to extend the scope of visibility to include many of the objects and conditions that were not visible in the early images. The visibility of a specific object depended on the relationship of its physical characteristics, contrast, and size, to three characteristics of the X-ray imaging process, contrast sensitivity, visibility of detail, and visual noise.



The two characteristics of the objects in the body can be represented by a diagram as shown to illustrate the factors affecting visibility.

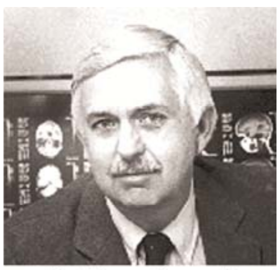
Following the introduction of X-ray imaging by Roentgen many inventions and developments have extended visibility to include many of the objects and conditions in the body.

Contrast Sensitivity of the imaging process determines the lowest contrast items in the body that can be visualized. The contrast between the soft tissues was the major challenge. Development of optimized X-ray spectra and film was a major contributor to increased visibility. Computed tomography (CT) extended visibility into the skull, which was the last major challenge.

Visibility of Detail, the small things, is limited by blurring within the imaging process. This was improved over the years with continuing developments of X-ray tubes with smaller radiation sources (focal spots) and receptors.

Visual Noise is a continuing challenge. It reduces the visible contrast between objects with low contrast in an image. A major factor is its conflict with reducing radiation exposure to patients. Noise is reduced by increasing the X-ray exposure *absorbed* in the receptor. It is the development of image receptors with increased X-ray *absorption efficiency* that has provided for the reduction of exposure to patients while maintaining the necessary image quality and Visibility.

About The Author


Dr. Perry Sprawls

The career of Dr. Sprawls as a clinical medical physicist began in 1960 on the faculty of a large medical facility, Emory University Medical School and Clinics, and as a consultant for the medical imaging industry. During this time, he worked with and had experience with virtually all the new and developing imaging technologies and methods and clinical applications. It is this personal experience that is the foundation for much of this article and the several other articles that are referenced.

A major interest and activity now is working with other medical physicists to preserve and share our rich history and heritage. This includes serving as a founding Co-Editor of the International Medical Physics journal History Series.

Contact: sprawls@emory.edu

ANNEX

FIRST INTERNATIONAL CONFERENCE

on

MEDICAL PHYSICS

Abstracts of Papers

I.C.M.P.

Harrogate
8th–10th September 1965

THE FIRST INTERNATIONAL CONFERENCE ON MEDICAL PHYSICS

HARROGATE, YORKSHIRE.
September 8, 9 and 10, 1965

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Prof. F. W. Spiers
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Mr. H. S. Wolff

Mr. G. S. Innes - Secretary

A

This volume contains the abstracts of the review papers and proffered papers to be read at the Conference. The time and place of each Parallel Session are shown. Participants are advised to bring this volume to the Conference.

A limited number of additional copies will be availabl e at the Conference at the price of £1, (One Pound) each.

SYNOPSIS OF

PARALLEL SESSIONS

PARALLEL SESSIONS

held in the

LOUNGE HALL

WEDNESDAY, Sept. 8th:

Session	A - 1	2.15 - 3.15	Solid State Dosimetry
	A - 2	3.25 - 4.25	Solid State Dosimetry
	A - 3	4.50 - 5.50	Microwave Absorption

THURSDAY, Sept. 9th:

Session	A - 4	2.15 - 3.15	Particle Beam Dosimetry
	A - 5	3.25 - 4.25	Dosimetry, Special Problems
	A - 6	4.50 - 5.50	Isotope Dosimetry

FRIDAY, Sept. 10th:

Session	A - 7	2.15 - 3.15	Computer Applications in Therapy
	A - 8	3.25 - 4.25	Computer Applications in Therapy
	A - 9	4.50 - 5.50	Dose Distribution

PARALLEL SESSIONS

held in the

CROWN HOTEL

WEDNESDAY, Sept. 8th:

Session	B - 1	2.15 - 3.15	Scanners
	B - 2	3.25 - 4.25	Scanners
	B - 3	4.50 - 5.50	Brain Scanning

THURSDAY, Sept. 9th:

Session	B - 4	2.15 - 3.15	Uses of Isotopes
	B - 5	3.25 - 4.25	Uses of Isotopes
	B - 6	4.50 - 5.50	Neutron Activation

FRIDAY, Sept. 10th:

Session	B - 7	2.15 - 3.15	X-rays, Spectra & Diagnostic Applications
	B - 8	3.25 - 4.25	X-rays, Spectra & Diagnostic Applications
	B - 9	4.50 - 5.50	X-rays, Spectra & Diagnostic Applications

PARALLEL SESSIONS

held in the

MAJESTIC HOTEL

WEDNESDAY, Sept. 8th:

Session	C - 1	2.15 - 3.15	Physiology and Medicine
	C - 2	3.25 - 4.25	Physiology and Medicine
	C - 3	4.50 - 5.50	Physiology and Medicine

THURSDAY, Sept. 9th:

Session	C - 4	2.15 - 3.15	Biological Systems & Measurement
	C - 5	3.25 - 4.25	Biological Systems & Measurement
	C - 6	4.50 - 5.50	Biological Systems & Measurement

FRIDAY, Sept. 10th:

Session	C - 7	2.15 - 3.15	Radiation Biology
	C - 8	3.25 - 4.25	Radiation Biology
	C - 9	4.50 - 5.50	Ultrasonics & Optical Techniques

PROGRAMME OF

PARALLEL SESSIONS

WEDNESDAY, Sept. 8th

SESSIONS A-1, A-2 AND A-3

Chairman: Prof. J. S. Laughlin
Vice-Chairman: Dr. R. E. Ellis

Paper No.	Presented by:
1	F. W. Spiers
2	E. Shuttleworth
3	G. P. Naylor
4	I. Berstein
5	R. P. Parker
6	B. J. Morley
7	J. Keller
8	M. Mihailovic
9	M. Kent
10	D. E. Herbert
11	J. R. Mallard
12	E. H. Grant

SESSIONS B-1, B-2 AND B-3

Chairman: Dr. G. L. Brownell
Vice-Chairman: Prof. J. Fowler

Paper No.	Presented by:
13	H. A. B. Simons
14	J. R. Mallard
15	S. O. Fedoruk
16	R. J. T. Herbert
17	B. Westerman
18	W. G. Walker
19	B. R. Pullan
20	A. Lansiart
21	B. J. Perry
22	J. McAlister
23	M. H. Sutherland
24	M. Akerman
25	F. C. Gillespie

WEDNESDAY, Sept. 8th

SESSIONS C-1, C-2 AND C-3

Chairman: Dr. B. Jacobson
Vice-Chairman: Dr. S. Rowlands

Paper No.	Presented by:
26	H. Schneider
27	J. Tigyi
28	R. L. Coren
29	C. Pallotti
30	W. T. Suermondt
31	B. A. Goddard
32	S. A. Vincent
33	D. Rowan
34	A. S. Velate
35	H. A. B. Simons
36	C. M. Cade
37	D. G. Tilston
38	M. Gembicki

THURSDAY, Sept. 9th

SESSIONS A-4, A-5 AND A-6

Chairman: Prof. J. Keller
Vice-Chairman: Prof. J. W. Boag

Paper No.	Presented by:
39	W. M. Preston
40	S. B. Field
41	R. E. Ellis
42	L. S. Skaggs
43	F. O'Foghludha
44	J. E. Robinson
45	R. E. Lawson
46	A. Rakow
47	N. G. Trott
48	E. F. Focht
49	E. M. Smith
50	C. E. Newton
51	C. A. Sondhaus

SESSIONS B-4, B-5 AND B-6

Chairman: Miss S. O. Fedoruk
Vice-Chairman: Mr. G. R. Newbery

Paper No.	Presented by:
52	R. Oliver
53	L. Burkinshaw
54	J. Shimmins
55	L. A. Hawkins
56	R. Hesp
57	B. I. Tyson
58	C. D. Field
59	M. R. H. Taylor
60	J. M. A. Lenihan
61	S. Osborn
62	J. Rundo
63	D. Newton
64	A. Batchelor

THURSDAY, Sept. 9th

SESSIONS C-4, C-5 AND C-6		Paper No.	Presented by:
Chairman:	Dr. D. V. Cormack	65	J. White
Vice-Chairman:	Dr. G. W. Dolphin	66	F. Tattam
		67	P. S. Lykoudis
		68	A. Kaul
		69	H. Branson
		70	R. Ellams
		71	C. Matthews
		72	P. R. J. Burch
		73	C. Kellershohn
		74	J. B. Dawson
		75	B. Jacobson
		76	N. L. Gregory
		77	S. Guha
		78	F. Hepburn

SPECIAL SESSION			
Chairman:	Prof. W. V. Mayneord	79	E. H. Belcher
Vice-Chairman:	Dr. S. Benner	80	G. E. Osman

FRIDAY, Sept. 10th

SESSIONS A-7, A-8 AND A-9

Chairman: Prof. J. Dutreix
Vice-Chairman: Prof. F. W. Spiers

Paper No.	Presented by:
81	J. Howarth
82	R. Bentley
83	J. C. Jones
84	J. S. Robertson
85	J. van de Geijn
86	C. S. Hope
87	W. A. Jennings
88	R. J. Shalek
89	K. A. Wright
90	J. Telich
91	P. G. Orchard
92	M. Cohen

SESSIONS B-7, B-8 AND B-9

Chairman: Mr. R. W. Stanford
Vice-Chairman: Prof. H. A. B. Simons

Paper No.	Presented by:
93	A. D. Rotenberg
94	P. Tothill
95	P. N. Goodwin
96	S. Lillicrap
97	G. A. Hay
98	M. Davison
99	A. Robinson
100	M. B. Heller
101	S. P. Ricci
102	J. R. Cameron
103	G. W. Reed
104	B. Keane
105	C. Greatorex

FRIDAY, Sept. 10th

SESSIONS C-7, C-8 AND C-9	Paper No.	Presented by:
Chairman: Dr. P. Failla	106	C. H. Marshall
Vice-Chairman: Prof. L. F. Lamerton	107	R. Oliver
	108	J. Ovadia
	109	M. L. Griem
	110	G. Poretti
	111	J. S. Orr
	112	B. W. G. Morgan
	113	D. V. Cormack
	114	J. A. Newell
	115	A. Sokollu
	116	J. McKie
	117	F. G. Parsons

ABSTRACTS OF

REVIEW PAPERS

Wednesday, Sept. 8th, at 11.45 a.m. in the Lounge Hall.

"COMPUTERS AND DATA PROCESSING"

by

Professor S. Gill,
Imperial College of Science,
London.

Although computers have reduced very greatly the time and cost of doing very long calculations, there are still limitations on what they can do. Whether a given task can be performed by a computer may depend on one or more of the following factors:-

> computing speed; internal storage capacity; availability of data in a suitable form; ability to produce output in the form required; and the possibility of writing a programme.

The latter requires that a mathematical procedure exists, suitably expressed; advances in programming techniques are giving us new forms of expression for programmes, and this goes hand in hand with the evolution of new methods of solving problems.

In scientific research, computers can be used both to elaborate the consequences of hypotheses and to analyse the results of experiments and observations. In the latter area there are current moves to bring computers into more intimate contact with the experimental equipment.

Thursday, Sept. 9th, at 9.00 a.m. in the Lounge Hall.

"BLOOD AND THE SMALLER BLOOD VESSELS"

by

Dr. S. Rowlands,
St. Mary's Hospital
Medical School,
London.

The viscosity of blood depends on its protein and cell content, and also on the rate at which it is sheared in the experimental measurements. There are other liquids which have similar properties, but there is one anomaly which seems unique to blood; if the viscosity is measured from flow-rates in tubes smaller than $\frac{1}{2}$ mm in diameter, then the narrower the tube the lower the viscosity.

The explanation is that red cells are driven, by a force of hydrodynamic origin, away from the wall of the tube where the shear rate is maximum towards the faster moving central stream. There is good reason to believe that the same effect occurs in vivo. In the very smallest vessels the cells of the blood fill nearly the whole cross-section of the tube, and another type of anomalous flow occurs. The pattern of this flow produces much more mixing of the plasma than would occur if no cells were present, and this mixing probably facilitates the gaseous exchanges which take place between blood cells and the tissues or the alveoli of the lungs.

It is likely that the deformability of the red cells is the most important factor determining the flow of blood through the smaller blood vessels.

Thursday, Sept. 9th, at 10. 00 a. m. in the Lounge Hall.

"THE PHYSICS OF HEARING"

by

Dr. B. McA. Sayers,
Imperial College,
London.

Physical studies of sensory systems are unique in that the overt response to an experimental procedure is often ultimately based on complex subjective phenomena of a little-understood kind. What a listener perceives is very much a function of the listener and is not available for direct objective inspection by the experimenter. A significant part of the task of elucidating the hearing mechanism thus necessarily involves specialized experimental techniques which can lead to adequately objective assessment of the data. The particular difficulties of the field, however, are centred on several main unresolved aspects of audition, in some of which engineering and physical techniques are particularly relevant.

First, although relations between acoustic waveform and basilar membrane response are becoming clear, the relationship between basilar membrane activity and perceived auditory impression is proving much more elaborate than might have previously been supposed. While information about the mechanical-to-neural conversion along the length of the basilar membrane is now available, even with simple signals the relevance of temporal fine structure in cochlear electrical activity to the identification of the signal is strongly debated.

Bekesy's work on the pure-tone mechanical response of the basilar membrane has permitted inferences about the time-course of membrane displacement at various positions in response to wide-band acoustic signals. Considerable evidence is available about the neural activity resulting from membrane displacement, although it is not certain if other than simple mechanical displacement of the membrane is relevant in the initiation of cochlear neural signals. Psycho-physical experiments based on these data have led to inferences about the architecture of neural pathways involved in the cross-comparisons of binaural hearing; other experiments have provided information about the relation between regional cochlear activity and the character of associated sound image perceived by the listener.

Second, the function and mode of action of many of the structures between the cochlear nerve and the auditory cortex and their role in a listener's perceptual behaviour, are understood only in a most incomplete way.

Third, the mechanism of the special human faculty for perceptual separation of simultaneous acoustic signals (as with separate but simultaneous speech messages) and the dependence of this ability on the physical parameters involved in spatial separation of the sound source, are both live topics of current work.

Finally, of many aspects of prosthetic devices, a particularly important one concerns the optimum use of the auditory pathway to support the visual sense (as in reading devices for the blind). Here, the problem is one of optimally coding the auditory presentation, and in a sense, is a problem of signal analysis.

In these and other aspects, concepts and techniques of modern physical science are relevant, and the review will also, therefore, consider the potential further applicability of such techniques in the further elucidation of auditory perceptual activity.

Thursday, Sept. 9th at 11. 45 a.m. in the Lounge Hall.

"MICROWAVE SPECTROSCOPY"

by

Professor D. J. E. Ingram,
University of Keele,
Keele, Staffordshire.

Spectroscopy employing microwave or radar wavelengths has developed very rapidly since the war, and one particular branch of this, known as electron resonance, has found a large number of applications in the field of medical physics.

This paper will begin by outlining the general principles of the two new techniques which have been developed over recent years, i.e. nuclear magnetic resonance and electron spin resonance. The experimental equipment that is required in these studies will then be briefly described, and this will be followed by a summary of the general features which are observed in the spectra in both cases. Particular attention will be paid to the splittings which arise.

The particular application of the two techniques to problems in biological and medical physics will then be considered. In the case of electron resonance, these applications arise both from the study of free radical reactions associated with metabolic and enzyme activity, and from a study of transition group atoms which may form an essential role in biochemical activity, such as the iron atom in haemoglobin. Very interesting information is also becoming available from the combined study of these different effects in which free radical and enzyme activity can be plotted against change in valency state of the associated metal atoms. Other fields of medical interest in which electron resonance is also playing an increasingly important part, such as the study of irradiation damage, will also be briefly summarized.

The particular applications of nuclear magnetic resonance will also be considered, both in the more general form, such as the estimation of fluid contained in vivo, and in the more specific applications on the structural analysis of biochemically important compounds.

Friday, Sept. 10th, at 9.00 a.m. in the Lounge Hall.

"THE PHYSICS OF CELL DIVISION"

by

Dr. G. G. Selman,
University of Edinburgh
Department of Genetics,
Edinburgh.

Before about 1940, nearly all the hypotheses that were advanced to account for mitotic activity carried with them the assumption that a single kind of force was responsible for all the observed movements. Since the publication of the monograph by Schrader (1944) on "Mitosis", most cell biologists have abandoned this idea as being too simple. The complexity of intra-cellular organization, and the fact that it is almost impossible to affect a single subcellular structure or process by experimental means without simultaneously affecting many others, may have discouraged the application of the experimental method to this important branch of biology. Nevertheless, during the last twenty years much useful information has been gathered from measurements made from time-lapse films of cells in division using phase-contrast microscopy and from birefringence measurements on the spindle and cell cortex of dividing cells. Electron microscopy continues to reveal ultra-structural complexity which is not fully interpreted (e.g. the microtubules of the spindle). Measurements have been made of the stiffness of the cell surface during cleavage. Although we do not understand how a metaphase plate is established or what brings about the anaphase movement of chromosomes, these questions can now be considered in biophysical or biochemical terms.

The plane of cell cleavage is determined by the position occupied by the equator of the spindle at the late anaphase stage. The contractility of the cell surface appears to play an important role in the cleavages of certain animal cells. In all forms there is a growth of new cell surface which usually takes place in the cleavage plane.

Among the more promising lines of present research are the attempts being made to study contractility in defined cell fractions, to work with isolated cell spindles and to use microbeams of ultraviolet light to study the anaphase movements of individual chromosomes.

Friday, Sept. 10th, at 10.00 a.m. in the Lounge Hall.

"FUNCTIONAL REPLACEMENTS,
(ARTIFICIAL ORGANS AND LIMBS)"

by

Dr. J. T. Scales,
Dept. of Biomechanics and
Surgical Materials,
Royal National Orthopaedic
Hospital, Stanmore, Middx.

The replacement of an organ or the correction of its function by an artificial member or device is neither new nor infrequent. Spectacles have been used for many centuries, while dentures are now required in such numbers that approximately 1,000 tons of polymethylmethacrylate dental polymer are used in the world annually.

Improvements in the treatment of disease or injury often follow developments in the field of chemistry, physics and engineering. Since 1945 a range of apparently inert plastic materials have become available which appeared to have suitable properties for a variety of surgical purposes. The limitations of devices constructed from these materials are now becoming apparent, and in orthopaedics in particular there is a return to the use of metals for major bone and joint replacements. Advances in the field of electronics, especially in the micro-miniaturization components, have made it possible to implant "active devices" in the body to control the function of organs, for example, the cardiac pacemaker.

The development of an artificial heart and its use in calves has recently led the Surgeon-General of the United States Armed Forces to prophesy that in twenty years artificial hearts will be in use.

We have the prospect of great and new opportunities in surgical treatment, but only a just appraisal of the hazards, judicious selection of both patients and materials, coupled with adequate standards of design and manufacture, can prevent many disorders.

Future progress is largely dependent on the close collaboration of the disciplines of biology and medicine, physics and engineering. Some of the biological and mechanical factors which can influence the successful outcome of replacement surgery will be discussed and illustrated with slides and a film.

Friday, Sept. 10th, at 10.00 a.m. in the Lounge Hall.

"FUNCTIONAL REPLACEMENTS, (ARTIFICIAL ORGANS AND LIMBS)"

by

Dr. M. Vitali,
Limb Fitting Centre,
Roehampton, London.

Functional replacement of limbs has been a topic for discussion between surgeons, engineers and prosthetists for many years. It has become apparent that even the most sophisticated mechanism would never replace a lost arm or leg but it may help in restoration of function, with a minimal amount of effort required.

With the progress of medicine and surgery, development of new materials and variety of new drugs, the expectation of life of an individual is much greater today, but the hazard of speed has resulted in an increase of road accidents. Drugs prolong life but fail to stop progress of such diseases as arteriosclerosis or diabetes, or may introduce complications of a previously unknown factor resulting, for example, in the thalidomide tragedy and congenital deformities.

It has become necessary to continue our efforts and to construct a team of specialists of different branches such as physiologists, neurologists, surgeons and physicists, to try and solve the problem of movement from every point of view. One has to remember that each patient is an individual, and certain variations of an original design may have to take place.

The main object of this paper is to give an outline of an existing modern type of prostheses for extremities, and to show what can be done for severely deformed children.

It is hoped that this short survey of our work will stimulate further co-operation and new ideas in all specialist fields.

Friday, Sept. 10th, at 11.45 a.m. in the Lounge Hall.

"WORK IN ABNORMAL ENVIRONMENTS"

by

Dr. K. G. Williams,
Vickers Research, Ltd.,
London.

The development of technological societies means that men have to work in environmental conditions which fall outside the limits for human survival. The depths of the sea and the strangeness of space must now be accepted as the frontiers of human exploration. Life in these environments is only made possible by engineering control of the environment in immediate contact with the man. But even with most advanced technology, physiological problems are still posed which influence the ability of man to live and work. Decompression sickness beneath the sea and weightlessness in space are among typical examples.

The glamour of such pursuits must not, however, be allowed to hide the fact that abnormal environments exist under standard atmospheric conditions. The extensive use of equipment and materials producing radiation, cybernation, a complex of transportation systems at increasing speeds and modern communication systems are among the technical problems which can influence human behaviour. The solutions to such problems are not always so clear-cut as those under dramatic situations. But because they influence a greater number of men their effect in the end may be more considerable.

The indirect influence of such abnormal environments in medical practice must not be underestimated. But in recent years abnormal environments have themselves become part of medical therapy. Hyperbaric medicine and units for the prevention of cross-infection exemplify this. Here both the medical staff and patients may be involved.

So the need to work in technical environments tends to spread through all aspects of society. As it does so, a general approach becomes necessary, for the solution of individual problems, often on an empirical basis, may in itself be uneconomic and not wholly successful.

ABSTRACTS OF

PROFFERED PAPERS

SOLID STATE DOSIMETRY

F. W. Spiers and G. Zanelli,
The General Infirmary, Leeds.

1. THE APPLICATION OF THERMOLUMINESCENCE TO PROBLEMS OF RADIATION DOSIMETRY IN BONE.

Thermoluminescent powders offer a unique opportunity to measure radiation dose in trabecular bone and on the surface of cortical bone. This calls for the use of thermoluminescent powders having a grain size smaller than normally found in commercially available salts.

The paper describes investigations of thermoluminescent response with variation in grain size and of the energy response in the photon energy range where photoelectric absorption is important. Methods are then described by which the fine-grain salt is introduced into the marrow cavities of specimens of trabecular bone, and removed for measurement after irradiation.

Some of the bone specimens are those for which the distribution of marrow cavity sizes has already been measured, and on the basis of which calculations of mean marrow dose have already been made. Comparisons are made between measured and calculated mean marrow doses. Further experiments compare the doses measured near cortical bone surfaces with those based on various theoretical treatments of the problem of secondary electron emission from bone.

E. Shuttleworth and J. F. Fowler,
Hammersmith Hospital, London.

2. LITHIUM FLUORIDE THERMOLUMINESCENCE DOSIMETRY.

Practical difficulties can arise in the use of thermoluminescence dosemeters. Agitation of lithium fluoride powder produces a spurious thermoluminescence, which can be suppressed by heating in an inert gas. Some investigations of this spurious thermoluminescence will be described. It has been found that the stored energy decays by 15% to 20% over a period of three weeks, and then largely recovers after a further few weeks. This recovery could explain why other laboratories have not reported decay after measurements over longer times.

Some applications and their problems will be described, including clinical measurements, intercomparisons between different centres by post, and finger-mounted dosemeters of low bulk.

G. P. Naylor,
Christie Hospital, Manchester.

3. SOME DEFICIENCIES IN THE PERFORMANCE OF CURRENTLY AVAILABLE LITHIUM FLUORIDE THERMOLUMINESCENT PHOSPHORS.

The limitations of lithium fluoride phosphors in the light of experience of their use in practical dosimetry will be discussed with special reference to:

a) deduction from a glow curve of the likely practical performance of a given phosphor,

b) dependence of response on radiation energy and its variation in phosphors with a non-linear light versus dose curve.

Some requirements for the "ideal" thermoluminescent phosphor will be indicated.

B. E. Bjarngard, R. C. McCall and I. A. Berstein,
Controls for Radiation, Inc., Massachusetts, U.S.A.

4. LITHIUM FLUORIDE PLASTIC DOSEMETERS FOR THERMOLUMINESCENT DOSIMETRY.

One of the desirable improvements in extending the usefulness of lithium fluoride thermoluminescence dosimetry is to make dosemeters which are easier to handle than the loose powder. In addition, it is desirable for medical applications to have dosemeters of various shapes and thicknesses, such as discs (100 to 200 ml in thickness), sheet, or rod.

Such dosemeters have been successfully fabricated using techniques of loading lithium fluoride phosphors in high melting polymeric tetrafluoroethylene and processing to desired configuration including thin films. These dosemeters have good energy independence and tissue equivalence and no danger of breaking.

Most other characteristics are determined by the properties of LiF itself. Special problems are associated with the choice of readout procedure, and the background phenomena during readout. Our experiences in overcoming these problems and in the use of LiF loaded polytetrafluoroethylene will be described. Some applications in radiology and personnel protection will be discussed.

SOLID STATE DOSIMETRY

R. P. Parker and B. J. Morley,
Institute of Cancer Research, Surrey.

5. P-N JUNCTION SURFACE BARRIER DETECTORS AS γ-RAY DOSEMETERS.

These radiation detectors, which are in many ways the solid state analogue of the gaseous ionization chamber, may be used as γ-ray dosemeters in both pulse-counting and DC modes. The former is the most sensitive method and may be used to measure dose-rates down to the order of 10^{-5} r/hr.

Less sensitive, but more convenient, measurements of dose-rate may be carried out by determining the radiation-induced potential across the P-N junction. This may be done by using a high impedance valve voltmeter, in which case the open-circuit voltage is found to be a logarithmic function of dose-rate over a range of exposure dose-rates. Alternatively, the short circuit current may be measured, when an approximately linear dependence on dose-rate results.

The paper will consider the relative sensitivities of these different methods and, in particular, will give information on the dependence on dose-rate, dose, energy and temperature for a number of different types of surface barrier detector. Ways by which certain adverse effects can be nullified will be described.

B. J. Morley,
Institute of Cancer Research, Surrey.

6. MEASUREMENT OF β-ACTIVITY USING SILICON SURFACE BARRIER DETECTORS.

There is a need for the measurement of low β-activities in small volumes within the body, for example, in the individual chambers of the heart, in the bladder, or in a tumour. Silicon surface barrier needle detectors, which combine small size with high sensitivity, are being developed for these purposes. Larger surface barrier detectors, already familiar to the nuclear physicist, are also being considered for superficial activity measurements.

The low energy response of the semiconductor devices is limited mainly by the noise level. The dependence of noise on operating bias and temperature has been investigated for several types of detector. The counting efficiencies for several isotopes in common use have also been measured as functions of depletion depth and temperature.

If the probe is to be used to scan an area of β-activity, e.g. to locate a brain tumour, then for sharp definition it must discriminate

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against bremsstrahlung. Consequently a study has been made of the relative counting efficiencies to β- and γ- radiations.

An important property of any device contemplated for routine use is its stability and useful life, and a progress report on those detectors under investigation will be given.

J. Keller, W. Katkiewicz and M. Szawlowski,
Central Laboratory for Radiological Protection,
Warsaw, Poland.

7. APPLICATIONS OF THE FIELD EFFECT TRANSISTOR (FET) TO THE MEASUREMENT OF IONIZATION CURRENTS IN MEDICAL PHYSICS AND HEALTH PROTECTION.

The development of the field effect device which has high input impedance and high transconductance has opened up new possibilities through its use at the input stage of an amplifier driven from a current source. The range of signals in which an unipolar device can replace an electrometer tube is studied. The current-driven characteristics of FET are presented, the influence of temperature on the FET performance is measured, and the temperature co-efficient and compensation considered.

A single FET current amplifier with gain of 5×10^5 and temperature drift of 10^{-11} amp/$^{\circ}$C is developed. An ionization chamber monitor suitable for use in radiation physics is described. It contains a unipolar unit at the input and a planar bipolar transistor at the second stage. The circuit used is extremely simple and the device is very small.

The paper gives an outline of further possible work in this field.

M. Mihailovic, V. Kosi, M. V. Mihailovic and Z. Milavec,
University of Ljubljana, Yugoslavia.

A THERMOLUMINESCENT DOSEMETER AND DOSIMETRY READER.

8. A dosemeter for routine use has been developed using calcium fluoride thermoluminescent powder. The CaF_2 powder has been built

into a specially developed enamel and fixed by the enamel to the silver support.

The enamel coating gives a good protection against atmospheric and other influences. The dosemeter is completely free of triboluminescence.

Five hundred dosemeters have been tested for loss of stored energy. Suitably stored dosemeters show no loss of stored energy after five weeks.

With an active surface of 1 cm^2 and the use of a standard RCA 6342-A photomultiplier for detecting the light, the device detects doses of ^{60}Co rays in the 100 milliroentgen range, and is linear up to at least 10^4 roentgens.

Suitable shields are used to correct the energy dependence of the response. For an unshielded dosemeter the ratio of the response at 40 kV eff/ to that for ^{60}Co rays is approximately equal to 4. The dosemeters are very simple to produce, and consist of a CaF_2 coating on a silver support 0. 12 mm thick and size 3 x 2 cm^2. The CaF_2 is coated with 1 mm of enamel.

The reading instrument integrates the thermoluminescence during the heating time, which is determined by an indra-red photoresistor. The doses may be registered by a recorder or simply read on an ordinary millivoltmeter. A system is built in to enable the reading of any dose with the same accuracy in any of the ranges: 0 - 100 mr, 100 mr - 1 r, 1 - 10 r and 10 - 100 r.

MICROWAVE ABSORPTION

M. Kent,
St. Thomas's Hospital, London.

9. TECHNIQUES FOR THE STUDY OF LIVING TISSUE BY E.S.R. AT 3 cm WAVELENGTH.

Special techniques have been developed during the past few years which enable measurements of E.S.R. signals from surviving animal tissues to be made; these are briefly described.

A multichannel analyser is also used to improve the signal-to-noise ratio by means of a continuous averaging technique. N successive sweeps of the E.S.R. spectrum are added in the memory of the analyser to give an improvement of $N^{\frac{1}{2}}$, and in addition, each channel of the memory takes the average of 10 samples of the signal so that the improvement becomes $(10N)^{\frac{1}{2}}$. The limit of the improvement has been found to be 100:1, and the optimum conditions of operation are at a sweep rate of 100 gauss in 4 - 8 seconds, with a time constant of 0.2 seconds.

With the use of differentiation facilities, the second derivative of the signal can be obtained automatically to give an easy and accurate measurement of the g-value of any signal; an accuracy of 1 in 10^3 - 10^4 has been obtained in g for signals from surviving tissue. The use of a magnetic tape recorder, in conjunction with the analyser, also permits the integration of the signal to give the total number of spins in the signal; the usual method of computation from a pen-recording gave errors of up to 10% in this integration, but the error is only 1% with the analyser. Finally, the analyser is invaluable in that backgro und spectra from sample cells can be stored and automatically subtracted from spectra obtained on samples and cell.

D. Herbert,
St. Bartholomew's Hospital, London.

10. THE EFFECTS OF MODE OF EXCITATION AND OF INTER-MOLECULAR COUPLING UPON THE PRODUCTION AND DECAY OF TRIPLET STATE MOLECULES.

The triplet excited states of molecules have been frequently implicated as possible transient intermediates in a wide variety of biologically significant energy transfer processes.

Recent theories have suggested, and recent phosphorescence studies have confirmed, that the probability of promotion of a molecule to its first excited triplet state is a function of the nature and strength of the inter-molecular couplings of the molecule and of the nature and intensity of the exciting radiation. More precisely, it has been found in several phosphorescence studies that the probability is enhanced by the coupling of the absorbing molecule with similar molecules via the hydrogen bond and van der Waal's interactions. This results in the formation of dimers, trimers, and polymers of high order (molecular excitons). The probability is also enhanced by the coupling of the absorbing molecule with dissimilar molecules through the exchange interaction to form complexes. Other phosphorescence studies have indicated that the probability of triplet state production may be greater for ionizing radiation than for ultraviolet radiation.

J. R. Mallard,
St. Thomas's Hospital, London.

11. ELECTRON SPIN RESONANCE SIGNALS FROM LIVING ANIMAL AND HUMAN TISSUES.

Commoner and Ternberg reported electron spin resonance signals from surviving tissues, which we have subsequently confirmed.

Using a much improved spectrometer, small slices of surviving tissues of 0.1 ml volume have been examined, including rat liver, kidney, heart muscle, muscle and brain, and also subcutaneous rat tumours. Considerable differences exist between the measured signals from tissue to tissue, the largest signals being observed from liver and kidney. The signals decrease with time (half period 30 minutes at 30°C), presumably due to death, and have g-values which suggest the presence of free radicals. The tumour tissues examined show much smaller signals than the normal tissue from which they were originally derived. Human blood also exhibits signals in the free radical region.

It has been found that the single signal previously observed is more complex, with up to 3 separate signals appearing at different g-values. Preliminary examination of cell fragments separated by centrifugation show that mitochondria exhibit similar signals to those observed in tissue, as shown by Sands and Beinert, but much work remains to elucidate the origin of the signals, which may perhaps be due to trace elements in addition to free radicals involved in respiratory processes.

A number of research and diagnostic uses may lie in this new field of physics applied to biology and medicine.

E. H. Grant,
Guy's Hospital, London.

12. THE ELECTRICAL BEHAVIOUR OF ALBUMEN SOLUTIONS AT HIGH FREQUENCIES.

The dielectric properties of solutions of egg albumen and bovine serum albumen have been investigated in order to study the electrical behaviour of these proteins in an aqueous environment.

The measurements were taken in the frequency range 250 - 1200 Mc/s between 0^o - 40^oC, using coaxial line apparatus working on the following principle. Radiation from a tunable triode oscillator is coupled through an isolating attenuator and low pass filter to the experimental cell containing the protein solution. The experimental cell is a short-circuited line, and thus produces a standing wave which is displayed on the standing wave indicator as a probe moves through the cell. From the standing wave ratio and the distance between the minima the real (ε') and imaginary (ε'') parts of the dielectric constant can be computed.

A few determinations were also carried out at 25^oC only between 500 kc/s and 200 Mc/s using a Boonton RX meter.

The results show a continuously falling dielectric constant over the range of frequencies examined, and this fact indicates the presence of a subsidiary (δ) dispersion region lying between the (β) protein dispersion and the (γ) water dispersion which are centred around 1 Mc/s and 3 kMc/s respectively. It is suggested that this δ region may be due to the water which is tightly bound to the protein molecule, although other possibilities cannot be excluded at present. This bound water would be expected to be present to the extent of 0.3 gm per gm of protein, which is in accordance with the value obtained by other methods.

The paper is concluded with a qualitative assessment of the biological significance of bound water.

SCANNERS

H. A. B. Simons, and J. M. Bailey,
Royal Free Hospital, London.

13. THE "FIGURE OF MERIT" OF DIFFERENT COLLIMATING SYSTEMS.

To enable a comparison to be made between the ability of different detecting systems to distinguish a region containing a different concentration of a gamma-emitting isotope from that of its surroundings, a "figure of merit" of the system was proposed by Dewey and Sinclair.

It is shown that this figure of merit can be calculated for simple collimating systems and plane targets, consisting of circles of uniform activity, in terms of non-dimensional parameters and the intrinsic detection efficiency of the scintillation crystal. Results are given of experimental investigations of figures of merit for various collimating systems, and targets of different radii are given which agree with the theory developed.

It is shown that the figure of merit is insufficient to enable a choice to be made of the collimating system which will give the best spatial resolution of the position of the target, and merely indicates the system which will best show the presence of a target.

J. Mallard and R. J. Wilks,
St. Thomas's Hospital, London.

14. A PHANTOM TECHNIQUE TO INTERCOMPARE THE PERFORMANCE OF RADIOISOTOPE SCANNING MACHINES.

A phantom technique is discussed to determine the performance of scanning machines in terms of the minimum diameter of tumour that can be detected at any given depth in phantom for a given clinical situation. Particular attention is paid to gamma cameras.

Hollow discs of 1 cm thickness and different diameters are filled with a substance of known activity, and lowered into a water tank 30" x 30" x 13". The count rate is determined for each disc at each depth, and the c.p.s. per unit area µc/ml (n_o) is calculated for each depth. With the discs removed and the tank filled with the radioactive substance, the background count rate in c. p. s. per unit area per µc/ml (N_o) is obtained for the tank.

By assuming that a clinical lesion approximates to a cylinder whose thickness is equal to its diameter, the appropriate value of n_o is found from the summation of adjacent superposed discs. A graph of

$$\frac{n_o}{\sqrt{N_o}} \cdot \frac{1}{p^2}$$

for cylinders is drawn against diameter for different depths in phantom, (p is the diameter of the image on the crystal of the camera).

The count rate changes which can just be perceived on the cathode ray tube display are determined as a function of area and background count rate. By drawing this function on the graph for a particular camera the intersections give the minimum diameter of cylinder which can be detected at each depth.

A comparison is made between 5" and 7' cameras and typical scintiscanners.

T. D. Cradduck, S. O. Fedoruk and W. B. Reid.
Winnipeg General Hospital, Saskatoon Cancer Clinic and
Nuclear Enterprises Limited, Winnipeg, Canada.

15. ASSESSMENT OF PERFORMANCE CHARACTERISTICS OF A SCINTILLATION CAMERA USING "DIFFERENCE" AND "RATIO" CIRCUITS.

The information resulting from a scintillation camera detection unit may be processed in two different manners to obtain the final image, depending on the choice of analogue computer used for the data processing. If the position signals are applied directly to an oscilloscope the resulting spot position is dependent upon the difference of the position signals derived in the detection unit, and this in its turn is dependent upon the total energy deposited in the crystal detector. If, on the other hand, the difference is taken, and then the ratio between this signal and the total energy signal is applied to the oscilloscope, the position of the spot is largely independent of energy deposited by the incoming photon in the detecting crystal.

A scintillation camera, utilizing an 11" diameter NaI (Tl) crystal, 2" Perspex light-pipe and nineteen 2" photomultipliers, has been used in conjunction with both a "difference" and a "ratio" type of analogue computer to determine the effects on performance of both types of data processing. The parameters which will be considered are sensitivity, spatial resolution and image distortion.

R. J. T. Herbert and M. A. Sheppard,
Liverpool Radium Institute, Liverpool.

16. SCINTILLATION COUNTERS WITH WEDGE FILTERS FOR "IN VIVO" THYROID UPTAKE MEASUREMENTS.

For a number of years two parallel Geiger counters have been used in Liverpool for thyroid counting such that the variation of sensitivity over the thyroid region is less than 5%. However, in this arrangement there is also a rather high contribution from extra-thyroidal radioactivity.

Conversion to a scintillation counter with a flat field collimator conforming to the recommendations of the I. A. E. A. Panel of Consultants (1962) is being considered. However, with a single counter there is considerably more variation over the thyroid region than with the two Geiger counters, although the extrathyroidal contribution is reduced, isocount curves being carried out on a phantom neck. The possibility of use of two counters, one directly behind and one directly in front of the neck with thyroid half-way between them was considered, but this gave a rather large extra-thyroidal contribution, though not as large as for the Geiger counters.

In order to make the thyroid region as uniform as possible two counters are being used, each directed anteriorly at 55° with 45° wedge filters. This is similar to the arrangement used for X-ray treatment of the larynx. Phantom measurements show a very uniform sensitivity over the anterior quadrant of the neck, with a variation not greater than 7% and a rapid fall-off outside this region.

Isocount curves for the various arrangements will be presented.

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B. Westerman, H. I. Glass and P. C. R. Turner,
Hammersmith Hospital, London.

17. AN 11" GAMMA CAMERA: SOME PRELIMINARY PHYSICAL AND CLINICAL RESULTS.

Results are presented of the physical performance of a commercial Gamma Camera, utilizing a sodium iodide detector 11" diameter and $\frac{1}{2}$" thick, in terms of its resolution, linearity, sensitivity and uniformity.

The resolution with the collimator was examined with bulbs of 1 - 5 cm diameter containing ^{131}I, ^{197}Hg or other isotopes, immersed in a water tank. The display of the scan has received particular attention, in order to quantitate the result. Comparisons of TV closed circuit, a photocopying method, and a tape recorder playback method, will be presented.

Some preliminary clinical results obtained on various organs, including kidney and brain scans, will be presented.

W. G. Walker and D. H. Pringle,
Edinburgh.

18. SOME FACTORS INFLUENCING THE DESIGN OF A PARALLEL MULTI-HOLE COLLIMATOR GAMMA SCINTILLATION CAMERA.

Two quantities of prime importance in the design of scintillation cameras are sensitivity and positional resolution. These two interdependent factors are functions of several system parameters, and these relationships will be considered.

The sensitivity of the instrument depends primarily on the geometrical efficiency of the gamma-ray collimator, the photoelectric absorption efficiency of the crystal and the efficiency of the electronic circuits. Similarly, the geometrical resolution is a function of the collimator resolving capabilities, Compton scattering in the crystal, crystal edge effects and the electronic circuits used.

In practical systems it is possible to design the electronic circuits such that their inherent losses and errors, dead time, gain non-linearity, etc. are negligible compared with those of the physical system, i. e. the collimator and the crystal. Inaccuracies, however, are introduced due to the analyser window width which must have a reasonable practical value in order to accommodate the width of the spectrum photopeak.

In the gamma-ray collimator the diameter of the parallel holes, the septal thickness, the depth of the collimator and the material used are of great importance, each affecting sensitivity and positioning resolution. The crystal thickness, diameter and position with respect to the collimator and the photomultiplier tubes are also important in optimizing these factors, and in practice a compromise must generally be sought between sensitivity and positional resolution.

B. R. Pullan and B. J. Perry,
St. George's Hospital, London.

19. SPARK CHAMBER SYSTEMS WITH A POSSIBLE APPLICATION TO MEDICINE.

Work is in progress to develop two spark chamber systems which may have applications in the location of radioactive substances in patients.

The spark chambers consist of two parallel plates, one made of lead and the other of aluminium mesh. The chambers are filled with a mixture of argon and alcohol vapour, and if a suitable voltage is applied between the plates a spark can be made to occur at the position of any ions produced in the gas. The chambers have a theoretical efficiency for detecting gamma-rays of the order of 1%.

Two methods of operating the spark chambers are being tried. In the first method, a constant voltage is maintained across the chamber, and after each spark discharged the voltage is removed for a short time. The circuit is similar to that used with a Geiger counter. It is hoped that spark chambers operating in this manner can be used with a parallel hole collimator to delineate the thyroid, using radioactive iodine. In the second method, which is to be used with isotopes emitting annihilation gamma-rays, the spark chamber and a scintillation counter are placed on opposite sides of the radioactivity of interest, and the chamber pulsed with a high voltage every time a gamma-ray is detected by the scintillation counter. The principle is the same as that employed in the annihilation gamma-ray camera.

It is hoped that this device will be of use in following small, inert pills containing positron-emitting isotopes in their passage through the gut.

A. Lansiart and C. Kellershohn,
Gif-sur-Yvette and Orsay, France.

20. SPARK CHAMBERS AND IMAGE INTENSIFIERS USED FOR X- AND γ- RAY SCANNING.

The spark chamber consists of three parallel electrodes placed in an enclosure filled with Xenon and methyl vapour. Its sensitivity is determined by the absorption of the radiation emitted by the radionuclide, through 3 cm of Xenon at atmospheric pressure. The resolution depends on the solid angle accepted by the collimator and on the range of electrons due to the photo-electric effect in the gas. In practice, the resolution is set by the collimator. The sparks are photographed with a camera having an aperture of f/11. A chamber with a useful diameter of 20 cm mounted on a lead grid was used to obtain pictures of the thyroid in patients using iodine-125, and of the kidneys and spleen using mercury-197.

For comparison, the performances of different detector arrangements using image intensifiers are described. A device has been developed which includes a radiological image tube where the zinc sulphide scintillator is replaced by a 3 mm CsI(Tl) crystal. A second high gain image intensifier is triggered at a threshold level set by the operator, by two small photomultipliers placed outside the solid angle defined by the lens optical coupling. In this way a very high signal-to-noise ratio is achieved. Results obtained in vivo with the experimental device are presented.

BRAIN SCANNING

B. Pullan, B. J. Perry and D. Dowsett,
St. George's Hospital, London.

21. A DISPLAY SYSTEM WHICH PRESENTS SCAN INFORMATION AS PATTERNS OF EQUAL SIGNIFICANCE ABOVE BACKGROUND OR THE CLINICALLY NORMAL.

A scan display system is in course of construction which gives both the uptake pattern and a measure of the confidence which can be placed in the pattern. This is achieved by displaying the scan in the form of areas of equal-significant difference between the observed uptake and the clinically normal uptake at a given anatomical site, or between the uptake and the background. The measure of significance employed is Student's "T" test. Computation is by analogue means, and the final display is on a cathode-ray tube. "Bright-up" of the tube is allowed only for areas which are different from normal or background, to a chosen degree of confidence.

The display is achieved by recording the original scan on tape at a very slow speed and replaying at high speed. Pre-recorded on the tape are position and line-synchronization pulses which control the scanner, and a set of pulses corresponding to the normal uptake pattern over the site in question. Assessment of significance over the whole area of the scan will take about two seconds. The system has the facility for displaying the scan that would have resulted if a coarser collimator had been used, so that in some cases the significance of doubtful areas of difference from normal can be improved.

The apparatus is designed particularly for the analysis of brain scans, but it can also be used for the display of data from other scan techniques.

J. McAlister,
St. Bartholomew's Hospital, London.

22. THE USE OF TECHNETIUM-99m FOR BRAIN SCANNING.

There has been considerable interest in the use of low-energy γ-emitters for clinical scanning and also in the use of short-lived isotopes. Following the reports of Harper et al, we started using Technetium-99m for brain scanning in November 1964. The first results were encouraging, even though the scans were carried out using crystals and collimators not specifically designed for low energy work. Measurements on biopsy material have confirmed a higher uptake in tumour than in normal brain tissue. The value of this isotope for brain scanning will be assessed and the effect of varying different factors, e.g. the time at which the scan is performed, the size of crystal and the collimator design, will be discussed.

M. H. Sutherland and J. Mallard,
St. Thomas's Hospital, London.

23. THE QUANTITATIVE ANALYSIS OF SCINTISCAN DISPLAYS WITH SPECIAL REFERENCE TO BRAIN SCANNING.

In many scans it is not possible to be certain of the presence or absence of an abnormality and it is, therefore, of value to estimate the degree of confidence with which an abnormality can be detected. On certain types of scan this may be done by comparing the count rate over different regions on the same scan, e. g. for the detection of space occupying lesions in the liver and in the centre of the head. In brain scanning, however, it is usually necessary to take into account the normal pattern of count rate over the head.

A technique is described in which the count rate over anatomically equivalent regions of the heads of different patients may be compared. This has been done by means of a simple rectangular grid, the elements of which vary in size from patient to patient. The average normal pattern of count rate has been determined in this way. The significance of the difference between the dot density in a given grid position of the equivocal scan and that in the corresponding region of the normal scan may be obtained by expressing the difference as a multiple of its standard error.

The normal pattern has been established for two scanning materials (arsenic and human serum albumin). Results show that the method will detect space occupying lesions which are not immediately detectable on the black and white scintiscan, although some may be identified as equivocal on the colour scan.

A method is also described for the automation of scintiscan analysis.

M. Akerman and G. Guiot,
C. M. C. Foch-Unité de Recherche de Neurophysiologie Chirurgicale,
Suresnes (Seine), France.

24. DIAGNOSIS OF INTRACRANIAL MASS-LESIONS BY ASSOCIATION OF ECHO-ENCEPHALOGRAPHY AND GAMMA-ENCEPHALOGRAPHY.

Five hundred patients have been tested by both methods;: 134 presented a confirmed intracranial process (90 hemispheric process; 19 tumours of the base of the brain, the pituitary region or the third ventricle; 25 lesions of the posterior fossa or the brain stem).

The ultrasonics apparatus had a screen graduated from 0 to 10 cm. It was adjusted in order to obtain the distance between the transmitter pulse and the back reflection of the outer surface of the opposite side equal to half the bitemporal diameter. Midline reflections were tested in the temporal position, and also in frontal and parietal positions, facing the longitudinal fissure, thus allowing an approximative localization of the process. A 2 - 3 cm displacement was considered as pathological.

The isotopic investigation used R. I. S. A. or mercury-labelled Neohydrin. The radioactivity was counted on about fifty positions of the cranium. With R. I. S. A., repeated measurements and the study of the radioiodine fixation curve in the lesion allowed, in a great number of cases, the diagnosis of the nature of the lesion.

A significant displacement of midline reflections was only found in 60% of cases, while observation of a radioactive focus enabled the localization of the process in 84% of cases.

When considering only hemispheric lesions, both methods gave similar positive results, (84% and 87%). Echo-encephalography gave better results than the radioisotope technique in hemispheric gliomas only.

False positive responses were more frequent with radio-isotopes (11%) than with ultrasonics (4%). Electro-encephalography could sometimes correct the few cases where both methods were deficient. 89% of neuro-surgical intracranial mass lesions were detected by the association of echo and gamma encephalography, and 94% of hemispheric lesions. By this association false positive results were reduced to 4%. Discordant results can help the diagnosis of the nature of the lesion. Association of a normal echo-encephalogram with a radioactive focus was found in arterio-veinous aneurysm, softenings, and post-operative scars without tumour relapse. Midline reflections displacement with a normal gamma-encephalogram was most often found with astrocytomas.

F. C. Gillespie and A. M. Boss,
Regional Physics Department, Glasgow.

25. THE EFFECT OF DIFFUSION ON THE CLEARANCE OF RADIOACTIVE INERT GAS FROM THE BRAIN.

One of the assumptions generally made when determining regional cerebral blood flow, by the measurement of the rate of clearance of a radioactive inert gas from the cerebrum, is that the error due to diffusion of the gas from the regions of high concentration to regions of low concentration is small and can be ignored. An estimate of this effect is made for several arrangements of experimental parameters and the results are checked experimentally. The effect of the error on previous reported results is discussed.

PHYSIOLOGY AND MEDICINE

H. Schneider,
Depts. of Medical Physics and Cardiology,
University Hospital, Utrecht.

26. THE REACTION OF THE DOG HEART TO ELECTRICAL DOUBLE PULSES IN VIVO.

The stimulation of the heart by means of electrical pulses of fixed duration, amplitude and repetition frequency is of some considerable medical interest.

Physical aspects of stimulation will be discussed. The reaction of the dog heart in vivo to double pulses of very short duration will be compared with other types of stimulation. Experience has shown that when double pulses are appropriately phased in relation to the beat, summation effects can be demonstrated. The experimental arrangements will be discussed.

J. Tigyi,
Biophysical Institute of Medical University,
Pecs, Hungary.

27. PHYSIOLOGICAL EFFECTS OF IONIZING RADIATION ON HEART AND SKELETAL MUSCLE.

Relatively small doses of different types of ionizing radiations were used in investigations on the isolated frog heart and skeletal muscles, from the point of view of a possible physiological effect. Both internal (incorporated) and external radiations were used with an energy range varying from 7 KeV beta-rays of tritium to 15 MeV betatron beams.

Physiological (biopositive) effects of radiation were observed in the following cases: (1) Restitution of the function of isolated, potassium-blocked, frog heart by ^{42}K, ^{24}Na, ^{32}P and ^{131}I isotopes. (2) Restitution of the function of frog heart by a 15 MeV electron beam. (3) Increasing excitability of isolated frog heart-ventricle by electron irradiation. (4) Rise of action potential amplitudes on isolated frog sartorius muscle. (5) Increase of excitability of tritium treated skeletal muscles. (6) Prolonged survival time of tritium treated muscles. (7) Enhanced excitability (decrease of threshold stimulus voltage) of ^{60}Co irradiated skeletal muscles.

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All these phenomena are characterized as ones in which the physiological function was restored or increased. A semi-conductor hypothesis is discussed as a possible theoretical explanation, with practical applications of these effects.

R. L. Coren,
Drexel Institute of Technology, Philadelphia, U. S. A.

28. UTERINE CONTRACTION AND INTRA-AMNIOTIC PRESSURE.

Results are presented of an analysis of the intra-amniotic pressure developed during the uterine contractions occurring throughout pregnancy. A simple model is developed mathematically, in which: 1) contraction takes place by the spread of activity from a pacemaker area, 2) a part of the myometrium cannot contract. Expressions are derived giving the pressure change in terms of the fundamental physical, elastic and contractible properties of the myometrium.

The analysis suggests that a quantitative study of the contraction and relaxation can best be made by examining the rate of pressure rise and the logarithm of the pressure respectively, as functions of time. In the pressure-rate representation one finds an initial linear rise ($dP/dt \sim t$), followed by a flat portion (dP/dt = constant) and a linear fall off ($dP/dt \sim -t$), representing the three phases of uterine activity. In the logarithmic representation the relaxation phase appears as a straight line. The slopes of these several lines and the pressures and times at their end points are related to each other and to fundamental tissue properties.

A study was made of several clinical pressure tracings, and qualitative and quantitative agreement with theory is found. The internal consistency of the theoretical model is very good, and agreement is excellent between the measured critical pressures and times and those derived from independent measurements. It is shown that the pressure-rate and logarithmic representations are extremely revealing of details of the active and relaxation processes. Certain deviations from the model and some systematic changes during the progress of labour are observed in this way. The significance of these features will be discussed.

C. Pallotti and G. Pallotti,
University of Bologna, Italy.

29. A MATHEMATICAL TREATMENT OF HAEMODIALYSIS IN THE ARTIFICIAL KIDNEY.

A study has been made of haemodialysis in the artificial kidney. The relevant differential equations have been integrated using constants appropriate to the problem. Curves have been calculated of the variation of concentration with time for different substances which have to be eliminated from the blood. These curves have been obtained for two values of blood volume and two flow rates. The form of the curves will be discussed and suggestions will be made for further work in this field.

W. T. Suermondt,
State University Hospital, Utrecht.

30. A BODY PLETHYSMOGRAPH FOR THE MEASUREMENT OF THE LUNG VOLUMES AND OTHER PARAMETERS OF THE MECHANICS OF BREATHING.

A constant pressure body plethysmograph is described with which it is possible to measure parameters of the mechanics of breathing and lung volumes.

With this type of plethysmograph the entrance is hermetically sealed with water and no bolts or levels are, therefore, required. It is possible to open the plethysmograph from the inside as well as from the outside; this adds to the mental comfort of the patient.

The problem with this type of plethysmograph is to obtain a fast response. To overcome this a special spirometerbell has been designed which has less inertia than a Krogh spirometer.

B. A. Goddard,
Dudley Road Hospital, Birmingham.

31. A FOETAL ELECTROCARDIOGRAPH.

The paper describes ways in which the foetal electrocardiogram, normally obscured by maternal signals and noise, may be obtained with increased clarity. Equipment built into a single unit is described which provides a foetal E. C. G. almost free of maternal signals and noise.

Improvement in the signal-to-noise ratio is achieved by adding signals obtained from several pairs of electrodes placed on the maternal abdomen. The maternal signal is then "gated out" by using signal delay provided by a magnetic tape recorder and pulse delay circuits. Further improvement in signal-to-noise ratio is obtained by feeding the successive foetal signals, accurately triggered, into a signal averaging device. The use of two such devices is described, - the first, a trace brightness integration system using an image storage tube, and the second an averaging computer; results from these instruments are compared. Traces are shown at each stage of signal improvement; photographs and circuit diagrams of the equipment are included, together with a block diagram of the whole apparatus.

Difficulties of foetal heart rate measurement are discussed, and an effective way of doing this is described.

S. A. Vincent,
Belfast, N. Ireland.

32. MECHANICAL AND ELECTRICAL MEANS OF CONTROLLING INCONTINENCE OF URINE.

The use of electrical pacemakers for heart conditions has led various workers to attempt similar methods in the treatment of incontinence of urine. In theory, two methods are available for aiding patients with incontinence of urine, particularly when it is due to spinal disease or injury.

One method attempts to make the bladder contract and empty its contents under the control of the patient by means of electrical stimulation. The other method attempts to make the bladder hold urine when the patient wishes to hold it, - voiding occurring in response to stopping the stimulation which is keeping the bladder outlet closed.

A method will be described of treating incontinence of urine which has been used in a series of 800 patients, and which is based on a mechanical concept of bladder control.

The act of passing urine can be stopped in normal people by slow, firm, upward pressure on the anal canal region. This pressure has been shown by cine-radiography to close the bladder outlet and to allow no urine into the urethra to cause discomfort. Appliances have been designed which maintain the pressure, and which are used for treating incontinence of urine. Cine-radiographs will be shown which illustrate the events occurring during the act of micturition, with particular reference to those mechanical effects which could be initiated by electrical methods.

D. Rowan and S. Alexander,
Regional Physics Department and Royal Infirmary, Glasgow.

33. EXPERIMENTAL EVACUATION OF THE BLADDER BY MEANS OF IMPLANTED ELECTRODES.

One of the principal problems in the management of the paraplegic patient is the occurrence of infection of the urinary tract as a consequence of bladder catheterization. In a recent review, incidence of severe urinary tract infection was found to be 74% and the incidence of permanent incontinence 60%.

We have investigated the use of implantable electrical stimulators for the paralysed bladder controlled by an external radio frequency transmitter. The principal advantages of this technique are that it does not interfere with the virginity of the urinary tract or with later efforts to establish a functioning reflex or automatic bladder.

The response of the bladder to electrical stimulation requires to be elucidated before the design of these units can be finalized. Experiments were carried out on dogs using direct stimulation to establish effective stimulus parameters and the optimum location and type of electrodes. Measurements were made of the intra-vesical pressure and the degree of bladder evacuation. The problems encountered are described and solutions offered, together with some observations concerning the mechanism controlling the resistance to bladder outflow.

A. S. Velate,
Tavistock Institute of Human Relations, London.

34. PHYSICAL METHODS AS AN AID TO PSYCHOLOGICAL RESEARCH.

A psychological research project requires the objective measurement of the interaction between normal mothers and babies in their own home.

New-born babies have been used in a hospital-based preliminary study of various psychological variables to calibrate these against the psychologist's subjective judgements. These measurements include E. M. G., respiration, heart-rate, motility and crying. The responses to controlled stimuli such as light, sound and movement are being investigated.

With validation of the chosen variables, miniature transducer-telemetry devices are being developed. With suitable methods of attachment, it is hoped to record with the minimum of restraint and discomfort. Methods of recording the mother's proximity to the baby will be investigated.

A flexible aerial-receiver system, possibly involving relay links, will enable the data to be fed to a multi-channel tape-recorder from any p art of the volunteer's home.

Recordings of 24-hour activity will be computer analysed for subsequent comparison of subjects and environments. This study will be a system-proving trial, since the number of experiments is unlikely to be sufficient for valid statistical analysis.

H. A. B. Simons and A. Elithorn,
Royal Free Hospital, London.

35. A DISPLAY AND RECORDING UNIT FOR A COMPUTER GENERATED PSYCHOLOGICAL TEST.

In the past little attempt has been made to design tests of intellectual functions in a systematic manner. The present paper describes an apparatus for presenting perceptual maze patterns which can be fully described mathematically, and which can be generated systematically by an electronic computer. The apparatus consists of a triangular lattice having the properties of Galton's probability board. The lattice has 16 rows, excluding the apex, giving 2^{16} pathways. 152 miniature filament bulbs are placed at the lattice points of the array, and are illuminated in a pattern controlled by a punched card.

The subject's task is to track with a stylus, from the apex to the base of the pattern, a path which passes through a given maximum number of illuminated intersections. The stylus makes contacts at the intersection points, and cold-cathode trigger tubes generate a 16 digit binary number describing the path taken by the subject which is recorded on punched paper tape.

A similar task in a pencil and paper form has proved clinically useful as a test of focal brain damage. The present apparatus will allow the generation and presentation of a large range of patterns and will greatly facilitate the analysis of solving strategies adopted by normal and abnormal subjects.

C. M. Cade, A. E. Hanwell and K. Lloyd-Williams,
S. Smith & Sons (England) Ltd. , London.

36. RECENT ADVANCES IN THERMOGRAPHY.

Research in Britain into infra-red thermography has included studies of breast cancer, placental location, rheumatism, burns and vascular disturbances. Speed of scanning is important in all of these, and raises difficult design problems.

The need to resolve small areas, yet to scan a total field large enough to provide reference points, means that many elements are viewed in each frame. High-speed scanning, therefore, implies wide electrical bandwidth, and this raises problems of signal-to-noise ratio. Depth of focus is also a problem: if this is too shallow thermographs give unreliable data due to loss of focus. Much focal depth, however, implies large numerical aperture, hence loss of signal power.

In order to maximize efficiency, the dynamic range at the display (i. e. the number of shades which can be distinguished) must be matched to the signal-to-noise ratio at the input. The choice of display is thus partly governed by basic physical parameters.

Examples are shown of 40, 000 - element clinical thermographs scanned in 30 seconds, and showing a total temperature excursion of 1°C from black to white, with more than 20 resolvable shades. The principles of scanner design optimization are discussed.

D. G. Tilston,
Regional Physics Department, Glasgow.

37. CARDIAC OUTPUT MEASUREMENTS USING Xe-133.

Cardiac output measurements using Xe-133 have been compared with direct Fick estimations using oxygen uptake. Both bolus and constant injection techniques have been used. The reliability and possible sources of error of this method, which enables rapid repeated measurements of cardiac output to be made, are discussed.

The method has been used for cardiac output measurements under conditions of high atmospheric pressure, and the effects of pressure on the cardiac output are discussed.

M. Gembicki,
Dept. of Internal Medicine of the Medical Academy, Poznan, Poland.

38. HAEMODYNAMIC CHANGES IN THYROID DISORDERS STUDIED BY ^{131}I - ALBUMIN.

Repeated haemodynamic examinations using ^{131}I human serum albumin as a tracer were carried out in patients with hyperthyroidism treated with ^{131}I and with hypothyroidism during thyroid replacement therapy.

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These studies were performed in 190 persons, of whom 31 without any cardiac and thyroid disfunction were taken as controls. Patients with hyperthyroidism were divided into two groups: (1) - 57 patients without electrocardiographic changes, (2) - 33 patients with thyrotoxic heart disease and usually with atrial fibrillation.

The remaining two groups consisted of 43 persons with normal thyroid function induced by ^{131}I treatment and 26 persons with hypothyroidism. This last group comprised patients with primary hypothyroidism as well as those with hypothyroidism induced by ^{131}I therapy of hyperthyroidism.

It has been found that in patients with hyperthyroidism without cardiac complications the cardiac output was greatly increased. On the other hand, in patients with thyrotoxic heart disease a decrease of cardiac output was observed. In patients with hyperthyroidism the pulmonary circulation time was shorter than in the control group. Also a diminution of the pulmonary blood volume was observed.

The normalization of haemodynamic parameters was observed after successful ^{131}I treatment of hyperthyroidism without electrocardiographic changes, but more difficult to obtain in elderly patients.

In hyperthyroidism with thyrotoxic heart disease we did not observe any haemodynamic improvement after ^{131}I treatment, although the thyroid function was normalized.

The thyroid replacement therapy in hypothyroidism gives rise to haemodynamic improvement in the form of shorter circulation times as well as the half time of the activity decline in the left heart and the rise of the cardiac output.

PARTICLE BEAM DOSIMETRY

W. M. Preston and A. M. Koehler,
Harvard University, U. S. A.

39. PROTON BEAM DOSIMETRY AND DOSE DISTRIBUTIONS.

A group at Harvard and the Massacusetts General Hospital has for five years used the proton beam from a 160 MeV synchro-cyclotron for medical and biological purposes. A nitrogen gas ionization chamber is calibrated with monoenergetic protons and a Faraday cup. The residual range of a proton beam is varied by a water absorber, and at suitable intervals the total beam flux is measured with the ionization chamber. The lateral flux distribution is explored with a small silicon diode having a resolution of about 0. 1 mm. We have checked experimentally the limitations, due primarily to multiple coulomb scattering, on the minimum practical diameters of pencil beams and on the thickness of "knife-edge" beams for use in radio-surgery.

Over 100 hypophysectomies have been performed, using a cross-fire technique in which the Bragg peaks of 14 proton beams (7 from each side of the head, about 8 degrees apart, in a plane) collimated by a 7. 15 mm diameter circular aperture are superimposed at the target, the pituitary gland. Isodose curves in the planes of the co-ordinate axes can be calculated graphically without too much trouble. More complete information has been obtained from a computer programme. Because of the proximity of the optic and ocularmotor nerves to the target, this method requires excellent but, we believe, attainable accuracy in the control of beam range.

S. B. Field, D. K. Bewley and C. J. Parnell,
Hammersmith Hospital, London.

40. DOSIMETRY OF CHARGED PARTICLE BEAMS.

The Medical Research Council cyclotron is designed to produce alpha-particle and deuteron beams of large currents, with a nominal energy of 7. 5 MeV per nucleon. Methods of measurement of the energies are described, and the dosimetry is discussed from a theoretical standpoint and related to experimental values obtained both by means of a Faraday cup and calorimetrically.

The techniques of irradiation of biological specimens are described, with special reference to the facility of variation of the linear energy transfer (LET) of both beams.

R. E. Ellis, S. Lovell, E. R. Rollinson, J. Rotblat and J. White,
St. Bartholomew's Hospital, London.

41. MEASUREMENTS ON A 15 MeV 750 mA ELECTRON LINEAR ACCELERATOR.

The commissioning measurements made with the new 15 MeV 750 mA electron linear accelerator will be described. The measurements carried out include the determination of the dose per pulse and the dose rate of X-rays and electrons under continuous running conditions using a variety of dosemeter systems. An estimate has also been made of the dose rate due to the dark current.

The energy spectrum of the electron beam has been determined using a magnetic spectrometer and has been compared with the electron range measured in aluminium and perspex.

The size and divergence of the beam has been studied using activated copper foils, and plans have been made to build a beam transport system to allow various experimental arrays to be permanently positioned.

The radiation protection measurements around the accelerator will also be described.

L. S. Skaggs,
University of Chicago, U. S. A.

42. A THIN FOIL CALORIMETER FOR ELECTRON BEAM DOSIMETRY.

Thin foil calorimeters of the transmission type have been developed as dosemeters for beams of fast electrons. The foil is designed to heat rapidly to an equilibrium temperature proportional to electron beam current, with the temperature being measured by a thermocouple. Recent development of D. C. amplifiers with low noise and good stability at sensitivities down to 10 nanovolts full scale, make the calorimeters usable at 10^{-9} amperes.

The foil may be made as thin as mechanical considerations allow, since both sensitivity and time constant are independent of foil thickness. For any given pair of thermoelectric materials and diameter of the beam intercepting part of the foil, the sensitivity is only dependent on the inverse of the time constant for temperature equilibrium. Time constants of the most sensitive calorimeters used have ranged between 2 and 5 seconds.

In the relativistic energy region above 10 MeV the response is energy independent within ± 2.5%, and at 5 MeV the response is only 4% less than that at 10 MeV. This result is due both to the density effect of electron loss in solid materials and to the escape of secondary electrons of high energy that result from close collisions in the foil. Another advantage of the dosemeter is its inherent independence of rate effects in pulsed beams of low duty cycles.

DOSIMETRY - SPECIAL PROBLEMS

F. O'Foghludha,
Medical College of Virginia, U. S. A.

43. THE EFFECT OF RADIATION ENERGY SPECTRUM ON THE USE OF THE RECIPROCITY THEOREM FOR INTEGRAL DOSE MEASUREMENT.

The calculation of the photon energy spectrum obtained from extended gamma-ray sources by matrix inversion of the scintillation pulse height spectra is reported.

The integral dose in an extended absorber arising from a point source of radiation may be determined from the reciprocity theorem of measurement of the dose at that point, arising from a uniform distribution of activity throughout the absorber.

The effect of photon spectral shape on integral dose obtained in this way is investigated by theory and experiment.

J. E. Robinson and R. S. McDougall,
University of Maryland, Baltimore, U. S. A.

44. ELECTRON BEAM INSTABILITY AND ISODOSE ASSYMETRY ASSOCIATED WITH A 35 MeV MEDICAL BETATRON.

Initial dosimetry measurements on a Brown Boveri 35 MeV betatron indicated poor reproducibility of electron beam isodose distributions, with marked shifts from measurement to measurement.

An investigation showed that beam position and shape depended strongly upon a given combination of electron energy and extraction voltage. For a given energy, small changes in extraction voltage produced large assymetries in the radiation field, as did small variations in energy at a constant extraction voltage. The variability was apparently limited to the plane of the "doughnut."

The magnitude of these distortions was great enough to result in grave clinical problems if left uncorrected. A workable solution for the problem has been devised and adopted. Two cylindrical ionization chambers have been mounted in the fringe radiation field on the inside of the collimator support structure. The amplified output of these chambers is fed to a null voltmeter located on the control console, and beam symmetry is indicated by a null reading between the two chambers. Beam symmetry is maintained by adjustment of the extraction voltage control, and to aid in fine adjustment an auxiliary rheostat has been placed in series with the main extraction control.

R. C. Lawson, D. M. Clare and D. E. Watt,
U.K.A.E.A., Chapelcross, Scotland.

45. (D,D) AND (D, T) NEUTRON DEPTH DOSE MEASUREMENTS IN A TISSUE-EQUIVALENT PHANTOM.

An elliptically-shaped phantom, filled with tissue-equivalent material, was exposed to collimated beams of fast neutrons from the D(d, n) and D(t, n) reactions. The components of absorbed dose were measured with Bragg-Gray type detectors at depth in the phantom for beams incident on the major and minor axes.

Thermal neutron flux distributions at depth were measured for various collimated beams incident on different sized phantoms. The experimental measurement of the diffusion length of thermal neutrons in tissue-equivalent liquid permits calculation of the transport mean free path, and hence the determination of an accurate flux depression factor for the lithium iodide detector used to measure the thermal flux.

The energy spectra of recoil protons change with depth in tissue, and the associated quality factors are discussed. The results are compared with the theories of Snyder and Neufeld, and of Randolph.

A. Rakow,
Deutsche Akademie der Wissenschaften zu Berlin,
Germany.

46. PHOTOGRAPHIC DOSIMETRY IN A PHANTOM

A method of producing isodensity curves by a direct photographic process not employing a microdensitometer will be described and illustrated. By a suitable calibration method most of the common sources of error in photographic dosimetry can be eliminated and the photographic density correlated with absorbed dose. The energy dependence of the emulsion has been investigated both experimentally and theoretically, and the magnitude of the errors involved assessed. In moving field therapy there is some compensation of errors, and good agreement is obtained between the absorbed dose and blackening of the emulsion.

ISOTOPE DOSIMETRY

M. F. Cottrall and N. G. Trott,
Royal Marsden Hospital, Sutton.

47. PROBLEMS OF DOSIMETRY IN TRACER INVESTIGATIONS.

The applications of radioactive tracers in diagnosis inevitably involve some irradiation of the patient. In order to estimate the dose arising, detailed information is required on the distribution and retention of the radioactive material in the patient. Unfortunately, at the present time relatively little data of the type required are readily available. For this reason, at the authors' hospital, an attempt is being made, using a low background multiple crystal whole body counting system, to study the retention of a variety of radioactive tracers in a considerable number of patients attending for routine diagnostic tests. The counting system is located in a shielded laboratory, readily accessible to the hospital wards and outpatients' department. Methods being developed for analysing the data obtained will be discussed, these include the use of the facilities of a large digital computer.

Whilst the analysis of data is inevitably a complex problem, the counting system itself is relatively simple and inexpensive, incorporating four 7.5 cm diameter x 5 cm long NaI (Tl) crystals, but it has been found to have adequate sensitivity and flexibility for many studies of this type.

Results obtained with a number of radioactive materials, including ^{131}I Hippuran, will be reported. The significance of these results in considerations of the dosimetry of the tests will be discussed.

E. F. Focht, E. H. Quimby and M. Gershowitz,
New York Hospital, Cornell Medical Center, U. S. A.

48. GEOMETRIC FACTORS IN ISOTOPE DOSAGE AND REVISION OF AVERAGE $\bar{g}$ FOR CYLINDERS.

Existing tables which have been assumed to be average g factors, ($\bar{g}$), for cylinders containing uniform distributions of radioactive materials, actually refer to a point on the surface of the cylinder at the end of the axis. Using Bush's method the actual $\bar{g}$ values for cylinders of various radii and lengths for an effective μ of 0. 028 have been calculated.

For the $\bar{g}$ for cylinders with no absorption, an expression of Bush has been set up in a form which can be evaluated by a computer. The ratio of $\bar{g}$ with and without absorption for each cylinder size gives a constant for that cylinder from which $\bar{g}$ for other absorption coefficients was obtained by another computer programme.

A scale factor method has been set up by which average or point g's can be obtained for any μ, if the value is known for one size object of any shape, and is to be obtained for another differing only by a scale factor.

Further computer programmes give tables of g at the centre of cylinders up to a length of 100 cm and radius of 35 cm for various absorption coefficients, for uniform and for surface distributions.

E. M. Smith, C. C. Harris and R. H. Rohrer,
Cornell Medical Center, U. S. A.

49. INTERNAL DOSE CALCULATIONS FOR ^{99m}Tc - AN ILLUSTRATIVE EXAMPLE OF CURRENT PROBLEMS IN INTERNAL DOSE CALCULATIONS.

^{99m}Tc emits a 140 KeV photon and decays with a six hour half-life. The specific gamma-ray constant is 0.72 R-cm^2/mc-hr, of which 29% is due to K_α and K_β X-rays (resulting from internal conversion.) These X-rays make up only 1. 2% of the total photon energy released. The $\bar{E}_\beta$ for ^{99m}Tc is 14 KeV/disintegration (resulting from conversion electrons, Auger electrons and low energy photons).

Classical methods for calculating the gamma-component of the absorbed dose resulting from low energy photons under-estimate the absorbed dose, when compared with Monte Carlo type calculations, by 17% for 80 KeV photons (photon energy similar to ^{197}Hg) and by 14% for 160 KeV photons (photon energy similar to ^{99m}Tc) if the radionuclide is uniformly distributed in a 70 kg standard man (ellipsoid).

These sources of error may be avoided if the Monte Carlo type calculations presented by Ellett et al are used. These consist of tabulated values for the fraction of the photon energy emitted that is actually absorbed for a given photon energy with a given radionuclide distribution in a phantom of given mass and shape.

^{99m}Tc in various chemical states (TcO_4^-, Tc-labelled serum albumin and Tc-sulphur colloid) is being increasingly used for various scanning procedures such as brain, liver, placenta, etc. The absorbed dose a patient receives from each of these procedures has been compared with that from the more conventional scanning agents. The dose received from 1 to 10 mc of ^{99m}Tc is less than, or similar to, the dose from other scanning agents, while giving much higher counting rates.

C. E. Newton, I. C. Nelson and K. R. Heid,
Pacific Northwest Laboratory, U.S.A.

50. TRANSURANIC ELEMENTS AND THORIUM IN MAN: ASSESSMENT, APPLICABILITY OF BIOLOGICAL MODELS AND NEEDED RESEARCH.

Progress in the development of methods for assessing body burdens of the transuranic elements and thorium has not kept pace with the increased exposure. The applications and limitations of the Langham model for readily soluble, and the Healy model for less soluble, plutonium for establishing internal depositions are reviewed. The need for prompt assessment of body depositions and the complications which arise from the variables introduced because of the influences of medical treatment are presented.

A case in point describes the results of fifty autopsy specimens from personnel who had possibly been exposed to plutonium, and who had been participants in a sensitive bioassay programme specifically designed for the detection of this nuclide. Fractional picocurie organ depositions of plutonium were found in all cases, but in only one case was there a definite indication in the urine analysis.

Current research and areas in which research is needed are discussed, particularly those leading to improved methods of interpretation of body burdens of the transuranic elements and thorium as a function of the bioassay data.

C. A. Sondhaus and D. C. Lawrence,
California College of Medicine, U. S. A.

51. THE USE OF SOFT X-RAY EMITTING ISOTOPES IN INTERSTITIAL AND INTRACAVITARY IMPLANT THERAPY.

Physical tissue dose distributions, shielding factors and illustrative examples of background exposure doses to personnel during source and patient handling are presented for a newly designed type of radioactive seed containing 9.7 day Cs 131. These data are compared with the corresponding ones for conventional radium therapy, and some biological results of preliminary animal experiments are presented. It is shown that dose distribution within 2 cm of a source array of Cs 131 is closely similar to that for radium, but that doses to neighbouring tissue, to the therapist, and to hospital personnel, can be all but eliminated. Implications for improvement and extension of implant therapy methods are discussed.

USES OF ISOTOPES

R. Oliver and G. T. Warner,
The United Oxford Hospitals.

52. A WHOLE BODY COUNTER FOR CLINICAL MEASUREMENTS UTILIZING THE "SHADOW SHIELD" PRINCIPLE.

As this equipment, which has been developed for routine clinical measurements of uptake or loss of radioactive isotopes (particularly ^{58}Co and ^{59}Fe in haematological investigations) weighs only some $4\frac{1}{2}$ tons, installation within an existing hospital building has been possible. Two 4" x $3\frac{1}{2}$" No. 1 crystals are mounted 36" apart, above and below a motorized couch. Collimators limit the central field viewed to 20" across the couch and 6" or 12" along the couch, additional protection preventing direct background radiation from reaching the crystals.

The patient is scanned as the couch drives between the detectors, a recording ratemeter providing a "profile" of distribution, and a scaler "traverse count" a measure of total activity. Not more than ± 5% variation in traverse count was observed with variation of position of a small ^{58}Co source within a waterfilled body phantom, and the count obtained for the same activity in solution throughout the phantom was within 2% of the average value for this small source. Good agreement has been demonstrated between percentage retention derived from whole body counts and from measurement of faecal activity.

L. Burkinshaw, A. R. Wilson, B. E. C. Nordin and C. B. Oxby,
The General Infirmary, Leeds.

53. MEASUREMENT OF THE RETENTION OF BONE-SEEKING ISOTOPES BY WHOLE-BODY COUNTING.

20 μc of ^{47}Ca or up to 30 μc of ^{85}Sr have been given in single intravenous doses, and retention of the isotopes has been followed by whole-body counting for periods up to 35 days. In some instances measurements were made (a) on a counter consisting of three large plastic scintillators grouped around a chair, and

(b) on a counter made up of four 6" diameter x 4" thick NaI (Tl) crystals, two above and two below a horizontal couch.

The results have been compared with retentions calculated from the excreted activity. The sodium iodide counter has also given information about the distribution of these isotopes within the body, and markedly different distributions between one individual and another have been observed.

J. Shimmins, and D. A. Smith,
Regional Physics Department, Glasgow.

54. THE MEASUREMENT OF BONE FORMATION RATE USING STRONTIUM-85.

^{85}Sr is used as a tracer of calcium to study "bone formation rate." 30 mc of ^{85}Sr are given intravenously in the form of $^{85}SrCl_2$. A whole-body counter is used to measure retention of this tracer until its remaining activity is no longer statistically significant. Serum samples are taken, and an integrated specific activity from the time of injection calculated. From these data the "bone formation rate" is calculated, using the method of Bauer and the formula for Retention/Integrated Specific Activity.

The time at which the retention is measured is aimed to be late enough for all the tracer to be incorporated into bone tissue, and early enough so that no significant amount of the tracer has been resorbed by bone destruction. The bone formation rate calculated by the second method is lower than that calculated by the method of Bauer, and evidence is offered to show that the differences are significant and cannot be explained by experimental errors. The work of others supports this conclusion.

L. A. Hawkins,
King's College Hospital, London.

55. THE DISTRIBUTION OF ^{22}Na IN BONE.

When ^{22}Na is administered to mammals, a small fraction becomes fixed in bone, with a biological half-life of approximately one ear. If deposition were even throughout the skeleton, the radiation dose would be trivial. However, there is evidence that the ^{22}Na is selectively concentrated in particular sites, such as the periosteum and Haversian systems in process of formation at the time of administration, and it is of interest to estimate the radiation dose to cells at these sites.

The paper describes preliminary results of a study of ^{22}Na in young and adult rats injected with up to 100 μc. These were then sacrificed at intervals from 1 day to 9 months, the long bones being assayed for ^{22}Na content. Serial transverse sections were prepared for autoradiography to determine the sites of deposition and, using quantitative microdensitometry, the local concentration of ^{22}Na, and from this the radiation dose to small soft tissue cavities has been calculated.

R. Hesp and B. Ramsbottom,
U.K.A.E.A. Windscale and Calder Works, Cumberland.

56. THE EFFECT OF SODIUM ALGINATE IN INHIBITING UPTAKE OF RADIOSTRONTIUM FROM THE HUMAN GASTROINTESTINAL TRACT.

An experiment performed with the co-operation of a normal healthy adult male volunteer has shown that sodium alginate inhibited uptake of radiostrontium from the gastrointestinal tract by a factor of about 9. In the first stage of the experiment 0.36 μc ^{85}Sr was administered orally 20 minutes after an oral administration of 10 g sodium alginate. 26 days later 0.48 μc ^{85}Sr was administered orally. In both stages of the experiment samples of excreta and blood were collected, and body retention of ^{85}Sr was measured by means of the Windscale Whole Body Counter. The degree of inhibition of uptake of radiostrontium provided by sodium alginate were approximately 9.3, 9.2 and 8.3, as assessed from urine, blood serum and body retention respectively.

B. I. Tyson, S. Genna, R. L. Jones, V. Bikerman, R. Graham and B. A. Burrows,
Boston University School of Medicine, Boston, U.S.A.

57. ELECTROLYTE STUDIES WITH A TOTAL BODY COUNTER.

In man the normal total body K^+ was found to be 152.5 $\pm$ 10.1 (n = 25) mEq/litre intracellular water from ^{40}K measurements and ^{14}C inulin and tritium spaces calculated by computer programme. Further, weight per unit height ratio was found to show good correlation with a ^{42}K calibration factor, thus when body configuration of patients could be pair matched with a control, ^{42}K calibration was unnecessary. In two patients with primary aldosteronism good correlation was found between metabolic balances and body ^{40}K in restitution of potassium deficits in excess of 500 mEq. Of 30 patients with hypertension, potassium deficits were found which correlate with the severity of the hypertension.

In 20 healthy controls, 18 males and 2 females, ^{47}Ca retention was followed for periods of up to 40 days, following I. V. injection of 2 - 6 μc of ^{47}Ca. This retention curve could be resolved into at least two components; the faster with a half-time of 3 - 6 days was not responsive to dietary calcium changes, while the slower had a half-time inversely proportional to the diet calcium, ranging from 40 to 150 days. In one patient with a healing fracture the slow component half-time was significantly increased; conversely, in a patient with advanced carcinomatosis of bone and renal acidosis the slow component was extinguished. In two controls exchangeable ^{47}Ca and ^{24}Na were measured simultaneously with ^{40}K. In one of these, oral arginine loading was carried out and negative balances of ^{40}K and ^{47}Ca were found during the period of arginine loading.

C. D. Field,
University of the West Indies, Kingston, Jamaica.

58. LIVER CIRCULATION - STUDIES USING ISOTOPE DILUTION TECHNIQUES IN THE ISOLATED PERFUSED LIVER.

The condition of the liver was studied with regard to the relative importance and possible interaction between the portal venous supply and the hepatic arterial supply. Experiments were carried out on isolated canine livers, which were perfused with blood via the hepatic artery and portal vein. Physiological parameters affecting the flow of blood through the liver were recorded throughout. Separate aliquots of red cells from the dog were labelled respectively with ^{51}Cr and ^{32}P, and then re-suspended in plasma to form whole blood.

The experiment consisted of an instantaneous injection of a small volume of ^{51}Cr-labelled red cells into the arterial supply, and a similar injection of ^{32}P-labelled red cells into the portal venous supply, or vice versa. The output of both isotopes through the hepatic vein was monitored, and isotope dilution curves obtained for each isotope separately by the use of a two-channel scintillation spectrometer and a special detecting arrangement.

The dilution curves so obtained were analysed to find the mean circulation time of each supply through the liver.

From a knowledge of the mean circulation time and the respective rates of flow an estimation of "arterial space" and "portal space" could be made. The variation of these spaces with variation of flow rates, arterial and portal pressures were investigated.

Preliminary results indicate a considerable compensating mechanism in the liver which tended to maintain a constant "total liver space" (i.e. "arterial space" plus "portal space").

J. A. Harwood and M. R. Taylor,
Physical Laboratory, Trinity College, Dublin, Ireland.

59. IRON 55 AND IRON 59 MEASUREMENT FROM BLOOD SAMPLES USING A CAESIUM IODIDE CRYSTAL.

The simultaneous use of the isotopes of ^{55}Fe and ^{59}Fe is now common practice in clinical studies of iron metabolism and absorption. Because of the very soft nature of the ^{55}Fe X-ray radiation, the problem of detecting the presence of ^{55}Fe is not easy. Two Geiger tubes with different windows and filling have been used, and a liquid scintillation method using two energy windows has also been employed.

The paper describes a method of measuring ^{55}Fe and ^{59}Fe employing readily available conventional crystal phosphors. A thin CsI (Thallium-activated) crystal was used as the detector and two energy windows, one covering the entire ^{55}Fe spectrum (apart from some low level noise), and the other the ^{59}Fe spectrum were employed. Efficiencies of 2% for ^{55}Fe and 10% for ^{59}Fe were obtained with 10% cross-counting of the ^{59}Fe during ^{55}Fe estimation.

In spite of the need for electroplating the samples, the technique is easier than with a liquid scintillator. The photomultiplier used must have very good noise characteristics, since the average number of electrons produced at the cathode by a ^{55}Fe photon is only of the order of 10.

Clinical results from a number of cases are given.

NEUTRON ACTIVATION

J. M. A. Lenihan,
Regional Physics Department, Glasgow.

60. CLINICAL APPLICATIONS OF ACTIVATION ANALYSIS.

The extraordinary sensitivity of activation analysis (representing an improvement of 1,000 or even 1,000,000 over alternative techniques of analysis for several elements) can be usefully exploited in a wide range of clinical problems.

The paper will illustrate these applications with reference particularly to work now in progress on: (a) trace element metabolism in tumours; (b) mineralization of teeth; (c) toxic hazards in dental practice, and (d) archaeopathology.

S. Osborn, and C. K. Battye,
King's College Hospital, London.

61. SOME ASPECTS OF NEUTRON ACTIVATION ANALYSIS IN VIVO.

In neutron activation analysis in vivo, the neutron dose must be kept small and the counting must, therefore, be correspondingly sensitive. The requirements for such a counting system will be outlined.

For such work in human subjects, in order to ensure uniform activation throughout the body, it is necessary for the neutron flux to have a wide energy range. The detectability of the various elements will be discussed in relation to experimental results in both man and animals.

J. Rundo and D. Newton,
A. E. R. E. , Harwell.

62. NEUTRON ACTIVATION ANALYSIS OF LIVING SYSTEMS: INSTRUMENTATION AND DATA PROCESSING REQUIREMENTS FOR RADIOACTIVITY MEASUREMENTS.

This paper discusses the requirements for gamma-ray spectrometric measurements of neutron-induced radioactivity in small animals and in man, for the determination of some of the major constituents. High sensitivity is a principal requirement when man is the experimental subject, because of the low doses of neutrons which may be administered; it may also be required for small animals because the increase in permissible neutron dose may be offset by the smaller body content and, therefore, smaller induced activity.

The determination of total body calcium by measurement of the induced 8.9- minute calcium - 49 requires repeated measurements of body radioactivity at short intervals in order to ensure that calcium-49 is being measured uniquely. This means that a fast read-out system is essential. The method used at Harwell will be described; the results of measurements on neutron-irradiated toads will be used to exemplify the possibilities of the technique and also some of the complications which can arise.

D. Newton and J. W. Smith,
A. E. R. E., Harwell.

63. NEUTRON ACTIVATION ANALYSIS OF LIVING SYSTEMS: IRRADIATION OF HUMAN SUBJECTS AND MEASUREMENT OF THE INDUCED RADIOACTIVITY.

Two important requirements of a method for the determination of elements in man by neutron activation analysis are: essential uniformity of irradiation throughout the body, both as regards intensity and energy distribution, and a counting system with a response largely independent of the distribution of the induced activity in vivo.

The authors will discuss how far these requirements are met by the techniques and equipment used recently at Harwell to estimate whole-body sodium, chlorine and calcium.

A. L. Batchelor and P. W. Edmondson,
Radiobiological Research Unit, Harwell.

64. SODIUM ACTIVATION IN GOATS EXPOSED EITHER BILATERALLY OR UNILATERALLY TO FAST NEUTRONS.

The level of activation of sodium in goats exposed to fission neutrons from a uranium converter plate in the reactor BEPO has shown a linear correlation with the dose measured in air at the place where the body of the goat would be exposed. The level of activation is essentially the same whether the irradiation is unilateral or bilateral. Current results suggest, however, that the biological outcome is different depending on whether the irradiation is unilateral or bilateral.

It is concluded that although the level of sodium activation is proportional to the "in air" dose, the biological outcome depends on the geometry of the exposure.

BIOLOGICAL SYSTEMS AND MEASUREMENT

J. White,
National Institute for Medical Research, London.

65. AUTOMATIC DATA PROCESSING TECHNIQUES APPLIED TO THE STUDY OF THE HYPOTHALAMUS.

It has been known for some time that the hypothalamus area of the brain plays an important role in the temperature regulation mechanism of the body. In this work the effect of temperature changes and other stimuli on the actual neurone cells of the hypothalamus are being investigated.

Neurone discharge impulses are picked up from the brain of a conscious rabbit by means of an implanted microelectrode, and are recorded on one channel of a tape recorder. Temperatures from various parts of the brain and body are measured by means of thermistors, and this information is recorded digitally on another channel, together with real time. During the experiment the temperature of the brain is varied by means of a heat exchanger attached to the carotid artery. On play-back of the recording the signal from the microelectrode is fed into a pulse height discriminator so that the activity of one neurone cell may be isolated. These selected pulses are passed on to a ratemeter or interval timer; the resultant neurone discharge rate or interspike interval is then printed or punched out together with information from the temperature and time channels. The information thus obtained is processed by means of a digital computer so that correlation of induced temperature changes in the hypothalamus with neurone discharge rates and temperatures of other parts of the body may be obtained.

The normal time scale for analyzing such experiments is of the order of weeks. The resultant analysis now depends upon the turn-around time of the computer, but if it becomes necessary to have the results available during the experiment on-line facilities or direct computer access may be used.

F. G. Tattam,
National Institute for Medical Research, London.

66. THE ACQUISITION AND PROCESSING OF DATA FROM BIOLOGICAL EXPERIMENTS FOR SUBSEQUENT COMPUTER ANALYSIS.

The paper raises the problem of acquiring and processing data in a form in which the results are perceived by the experimenter's eyes. It is suggested that a television camera can sometimes be a very useful tool in these instances. Several possible applications of a television scan system are mentioned, and a method of measuring the areas of the inhibited zones on an antibiotic assay plate is discussed in more detail.

In this application the zones to be measured are arranged in some predetermined way on the assay plate. An illuminated graticule is mounted behind the plate, so that the graticule lines can be seen distinctly only in the clear zones to be measured. The graticule pulses on the video waveform are counted for all the scan lines passing through a particular square area containing the zone to be measured. The area of the inhibited zone is proportional to the number of counts. The instrument punches out the result onto paper tape in a form suitable for statistical analysis on a digital computer.

P. S. Lykoudis,
Purdue University, Lafayette, Indiana, U. S. A.

67. THE FLUID MECHANICS OF THE UPPER URINARY TRACT.

The transfer of urine between the kidneys through the ureters to the urinary bladder is examined. The motion of the flexible boundaries of the ureter is assumed to be known (harmonic) and such quantities as velocity profiles and pressure distributions inside the ureter are determined as a function of space and time. The theoretical findings agree rather well with measurements of pressure performed through catheterization (urograms).

A "universal constant" is found for all healthy ureters linking the frequency and the speed of the contractile wave, the rate of urine discharged, and the minimum diameter of the lumen during contraction. The work explains why attempts documented in the medical literature to correlate two of the above quantities at a time have failed to yield information (such as rate of discharge with frequency of contraction). This finding suggests that controlled experiments in which all of these quantities are measured are necessary. If the theory is correct, any deviation of the experimentally measured "constant" of a particular ureter will signify a pathological condition.

The work concludes that for the transfer of urine to the bladder it is necessary that the contractile wave arrive very close to the ureterovessical junction. It is thus shown why urine is not transported in those cases for which the lumen is open but the lower part of the ureter is contraction-wise inactive.

A. Kaul,
Max Planck-Institute for Biophysics, Frankfurt/Main, Germany.

68. INVESTIGATION OF POTASSIUM DEPLETION BY WHOLE-BODY COUNTING AND FLAME PHOTOMETRY.

Disorders of potassium metabolism are usually investigated by measurement of potassium concentration in blood plasma. In recent years some investigators have also measured red cell potassium as representative of intracellular potassium, although erythrocytes clearly differ from other body cells in both morphology and function.

We have, therefore, investigated total body potassium by whole-body counting as well as making measurements, by flame photometry, of potassium concentrations in plasma, erythrocytes, diet and excreta. So far two short series, each of four patients, have been studied.

In one series, daily ingestion of 200 mg of Chlorthalidon (a saluretic) for 8 days produced an average depletion of 7.7 per cent, or 11 g, in total body potassium. The measured decreases of 27.5 per cent and 3.1 per cent respectively, in the potassium concentrations of plasma and erythrocytes correspond to a total potassium depletion of only 4 to 6 g, compared with the total loss of 11 g measured by whole-body counting. The tests demonstrate that depletion in the intracellular potassium is greater than that observed in erythrocytes.

In the second investigation, whole-body counting of persons maintained on a low potassium diet for periods of 4 - 8 weeks showed an average potassium loss of 9 per cent, or 14 g. Potassium losses calculated from flame photometer measurements of potassium in diet and excreta were in agreement with the whole-body counting results within about 10 per cent.

The experimental methods and results of both series of tests will be discussed.

J . O. Lawson and H. Branson,
Howard University, Washington, U. S. A.

69. A FOUR COMPARTMENT MATHEMATICAL MODEL OF THE KIDNEY-BLADDER SYSTEM.

In experiments where materials labelled with isotopes are excreted through the kidney into the bladder, or in animal experiments with labelled materials introduced by puncture into the kidney, a reasonable model for mathematical analysis results from considering the material as being introduced into a tube (compartment a_1), from which it diffuses into the plasma (compartment a_2). The labelled material diffuses from the plasma into other tubes which may be lumped together as one (compartment a_3) and finally all tubes empty into the bladder (compartment a_4). A set of equations describing this system is:

$$\frac{\partial a_1(x,t)}{\partial t} = P_{12}\left[a_2(x,t) - a_1(x,t)\right] - v\,\frac{\partial a_1(x,t)}{\partial x}$$

$$\frac{\partial a_2(x,t)}{\partial t} = \frac{P_{21}+P_{23}}{P_{12}+P_{32}}\left[P_{12}\,a_1(x,t) + P_{32}\,a_3(x,t) - (P_{12}+P_{32})\,a_2(x,t)\right]$$

$$\frac{\partial a_3(x,t)}{\partial t} = P_{32}\left[a_2(x,t) - a_3(x,t)\right] - v\,\frac{\partial a_3(x,t)}{\partial x}$$

$$\frac{d}{dt}\left[S_4(t)\,a_4(t)\right] = v\left[\frac{\partial}{\partial x}\left\{S_1 a_1(x,t) + S_3 a_3(x,t)\right\}\right]_{x=e}.$$

The solutions for different initial and boundary conditions are expressed as integrals which have been solved numerically on an IBM 1620 digital computer. Graphs of the solutions and experimental results are compared.

R. Ellams,
National Institute for Medical Research, London.

70. COMPUTER ANALYSIS OF RENAL FUNCTION STUDIES.

Renal function studies using tracer techniques are an accepted diagnostic tool. The analysis of results has in the past been largely quantitative, but it is hoped that a quantitative study of the results will yield a more precise diagnosis. The paper outlines the derivation of an adequate model of the renal system using analogue techniques, and goes on to discuss the results so far of a study using analogue, digital and hybrid techniques to provide a routine analysis of renal function data.

The techniques developed are applicable to tracer studies of other compartmental systems.

C. M. E. Matthews, D. Read and E. J. M. Campbell,
Hammersmith Hospital, London.

71. ANALOGUE COMPUTER STUDY OF CO_2 STORES AND CONTROL OF VENTILATION.

The control of ventilation by means of tissue P_{CO_2} or CO_2 concentration has been simulated with an analogue computer by Grodins et al, and this simple model has later been extended by others. All these models assume that the rate of exchange of CO_2 between blood and tissues depends only on blood flow. However, observations in man of the rate of rise of mixed venous P_{CO_2} during re-breathing from a small bag, and of the kinetics of distribution of $^{11}CO_2$ and ^3H_2O indicate that CO_2 in blood exchanges vary rapidly with CO_2 in extracellular fluid, and that exchange between extracellular and intracellular CO_2 is comparatively slow.

We have simulated a model which includes exchange rates due to blood flow, and to exchange between extracellular and intracellular pools. Each of these rates becomes the limiting factor under different circumstances. The predictions of the model will be compared with experimental results for re-breathing from a bag, a step function change in inspired CO_2, hyperventilation, and others. The implications of the modifications made to Grodins' model will be discussed.

P. R. J. Burch,
The General Infirmary, Leeds.

72. MATHEMATICAL ASPECTS OF THE AGE- AND SEX-DISTRIBUTIONS OF CERTAIN DISEASES.

It has been found that when a 'latent period' is allowed for, the age- and sex-specific prevalence (N_t), and/or initiation-rates, (dN/dt) of many non-malignant, chronic diseases, fit one of the following mathematical expressions:

$$N_t = P_o (1 - e^{-kt})^n \quad \ldots (1)$$

$$dN/dt = n\,k\,P_o\,e^{-kt} (1 - e^{-kt})^{n-1} \quad \ldots (1a)$$

$$N_t = P_o (1 - e^{-kt^r}). \quad \ldots (2)$$

$$dN/dt = r\,k\,P_o\,t^{(r-1)}\,e^{-kt^r} \quad \ldots (2a)$$

$$Nt = P_o (1 - e^{-kt^r})^n \quad \ldots (3)$$

$$dN/dt = n\,r\,k\,P_o\,t^{(r-1)}\,e^{-kt^r} (1 - e^{-kt^r})^{n-1} \quad \ldots (3a)$$

P_o is a constant, equal to the proportion of the population at (genetic) risk with respect to the disease.

k is found to be a constant throughout postnatal life.

n may take values from 1 to at least 6.

r may take integral values from 1 to 5.

It will be seen that these are all stochastic equations. Equation (1) gives the age-specific prevalence of a condition that is initiated by at least n independent random events, each of average rate k per individual. Equation (1a) is the differentiated form of (1) and describes age-specific initiation-rates.

Equation (2) describes the age-specific prevalence of a condition that is initiated by r dependent random events of average gross-rate k per individual, and (2a) is the differentiated form giving initiation-rates.

Equation (3) combines equations (1) and (2) and describes the age-specific prevalence of a condition that is initiated by n independent sets of r dependent random events.

Examples of the fit of data to these equations will be shown. The simplest - and indeed the only plausible - interpretation of the conformity of numerous data to these equations is, that various diseases are initiated by independent and/or dependent random events. Some of these diseases (inflammatory polyarthritis, rheumatoid arthritis, systemic sclerosis, chronic discoid and systemic lupus erythematosus, Hashimoto's thyroiditis, multiple sclerosis) are widely believed to be "autoimmune." It will be suggested that the pathogenesis of such diseases (and many others) is best interpreted in terms of Burnet's 'forbidden-clone' concept of disturbed-tolerance autoimmunity.

C. Kellershohn and P. de Vernejoul,
Commissariat a l'Energie Atomique, Orsay, France.

73. APPLICATION OF THE LAPLACE TRANSFORM TO THE STUDY OF A CATENARY SYSTEM UNDER PULSATORY WORKING CONDITIONS.

The variation of radioactivity in terms of time, in a series of cavities in succession, of constant volume, passed through a fluid with constant flow, after "instantaneous" up-stream injection of a radioindicator, is given by the solutions of a differential linear system with constant coefficients. These solutions are identical with the well-known relations of Bateman, which give the activity of the different members of a radioactivity family.

In the case of pulsating cavities in succession passed through a fluid with a flow which is itself pulsatory, the solutions are those of a differential linear system with periodical coefficients appearing like a generalization of Bateman's solutions with a periodical modulation. The Laplace transform, in principle available for the solution of a system with constant coefficients, remains nevertheless very useful to obtain these generalized solutions.

After having studied the case of the dilution of an indicator in a single pulsatory cavity, the theory is applied to two pulsatory cavities in series (ventricles) separated by a constant parameters system (pulmonary circulation). We explain the shape and characteristics of the curve representing the variation of the precordial radioactivity in terms of time (radiocardiogram). The theoretical interpretation given is applied to the determination of ventricular volumes and left-to-right shunts. Finally, the consequences of the pulsatory characteristics of flow in heart chambers on the classical Stewart-Hamilton formulae enabling flow and volume measurements are examined.

J. B. Dawson,
University of Leeds.

74. ACCURACY AND DETECTION LIMITS IN THE SPECTRO-CHEMICAL ANALYSIS OF CLINICAL MATERIAL.

This paper will consider the problem of the accuracy and detection limits of spectrochemical methods used in the estimation of elements in clinical material, particularly in systems using a photomultiplier as the radiation detector, and with special reference to reproducibility and to the validity of the calibration procedure.

The detection limit for any element (taken as the concentration of the element producing a signal equal to twice the standard deviation of the background) will be considered in relation to a multi-channel high speed scanning spectrophotometer which has been developed for simultaneous emission and absorption spectrophotometry. This apparatus, which employs an oscillating grating, has been designed to integrate and record the intensities of the emission times from up to six elements simultaneously. P rocedures will be outlined by which reproducibilities of ± 0.5 to ± 1 per cent (standard deviation) can be achieved with an absolute accuracy of ± 2 per cent.

B. Jacobson and P. Edholm,
Karolinska Institutet, Stockholm, Sweden.

75. REFLECTION SPECTROPHOTOMETRY IN VIVO.

Research in atherosclerosis is hampered by the inability to study the development of atheromatous plaques in vivo. Thus, the effects of different therapy upon these plaques cannot be compared. For this reason we have developed a method of estimating the degree of aortic atheromatosis.

The technique is based on the difference in optical reflection spectra between atheromatous plaques and the normal aortic wall, utilizing two light guides consisting of flexible bundles of small glass fibres. Light is carried to the aortic wall through one light-guide, and the reflected light is transmitted back through the other light-guide to a measuring system.

Analogue electronic circuits are used for quantitative evaluation of the reflected light intensities. The ratio of reflected intensities is recorded independently of the absolute values, which vary with the degree of contact between the aortic wall and the tip of the catheter enclosing the light-guides. Also, the circuits indicate when too thick a layer of blood occurs between the catheter and the wall.

N. L. Gregory,
National Institute for Medical Research, London.

76. A RADIO FREQUENCY MASS SPECTROMETER COUPLED TO A GAS CHROMATOGRAPH FOR THE STUDY OF BIOLOGICAL EXTRACTS.

The mass spectrometer described was designed specifically for use with a gas chromatograph in the identification of scarce and impure chemical compounds of biological origin, and represents an attempt to combine high sensitivity and rapid scanning with moderate resolution.

The sample enters the spectrometer in the continuously flowing helium carrier gas stream through a heated metal inlet valve and stream splitters. Ionization is by electron impact at 30 eV.

Analysis is carried out at an ion energy of about 130 eV by square wave potentials applied between alternate members of a chain of twelve aligned grids. The square wave frequency is swept repetitively from about 800 Kc/s to 200 Kc/s in a period of about 15 secs to cover a mass range of from 16 to 200 atomic units.

Mass calibration is by means of calibration pulses derived from a crystal oscillator. The pulses are recorded with the mass spectrometer, and direct measurement of ion mass is possible to within one mass unit up to mass 100, and with reduced accuracy to mass 200.

In preliminary work satisfactory spectra have been obtained from chromatograms of .05 μl of single substances.

S. Guha and A. Richardson,
St. Louis University School of Medicine, Missouri, U.S.A.

77. PULSATILE ELECTROMAGNETIC PUMP.

The use of an electromagnetic field for the circulation of fluids has been tested and verified. From this, an electromagnetic pump consisting of no moving parts, and capable of circulating physiological saline (0.9%) and blood has been developed. The pump normally operates with alternating current, but under special circumstances direct current may be used.

By appropriate modulation of the electric and magnetic fields, both steady and pulsatile flows, or a combination of both, has been obtained.

The application of this device as a urinary bladder pump, in a heart-lung machine, and for vascular frequency response testing is under investigation.

F. Hepburn,
The General Infirmary, Leeds.

78. INCREASED PATIENT SAFETY FROM THE USE OF LOGICAL AND SIMPLE CONTROL-TAP SYSTEMS FOR INTRAVASCULAR PRESSURE RECORDING.

During routine cardiovascular investigations pressure monitoring apparatus is often coupled directly to the patient's vascular system, and considerable danger exists if methods of changing from one procedure (pressure recording, zero setting, calibration and catheter or manometer flushing, etc.) to another are not absolutely safe. Complications can vary in character from catheter blockage, due to inadvertent entry and clotting of blood and accidental continuous flushing of the catheter into the patient, to such untoward occurrences as the application of calibration pressures to the patient instead of the manometer, and the possible fatal consequence of air injection into the patient.

The functional requirements of a tap system have been analysed and logical design used to include the desirable safety restrictions. One system has been developed that gives safe, comprehensive control, using four conventional three-way taps logically grouped and so arranged that the positions of the tap handles themselves prevent undesirable linkages.

The functional requirements are collected into four groups which concern: (a) manometer standardization, (b) character of the record, (c) supplementary actions and (d) flushing procedures. Each group of activities can be controlled by a single three-way tap, which automatically caters for the necessary restrictions.

The use of logically designed taps, in which the lever covers the outlet not connected, provides mechanical safety as well as a quick means of checking the tap settings.

Suitable tap labelling can be used to provide a reminder to check the positions of other relevant taps when changing to a new procedure. This, together with the avoidance of possible complications, reduces the risk to the patient and errors due to preoccupation of inexperienced operators.

THE ORGANIZATION OF MEDICAL PHYSICS

E. H. Belcher, M. Cohen, R. A. Dudley, G. Gomez-Crespo, G. J. Hine, J. E. Varela and H. Vetter.

79. THE WORK OF THE INTERNATIONAL ATOMIC ENERGY AGENCY IN THE FIELD OF MEDICAL PHYSICS.

An important part of the work of the I. A. E. A. lies in the field of medical physics. This work embraces not only the provision of training facilities through fellowships, exchange programmes and training courses, the sending of technical assistance in the form of visiting experts, equipment and supplies and the organization of conferences, symposia and seminars, but also a large number of research and international standardization projects and a variety of scientific and technical information services.

The I. A. E. A. has organized four international training courses on medical applications of radioisotopes and two advanced seminars on the physics of radiotherapy. A series of advanced seminars on medical applications of radioisotopes is planned. More than 30 experts in medical physics have undertaken assignments of periods from 3 to 12 months in different countries of the world. The I. A. E. A. 's research contract programme is concentrated on a limited number of specific topics involving studies with radioisotopes. Co-ordinated research programmes, for example, on the use of radioactive calcium in the study of bone metabolism and on the applications of whole-body radioactivity measurements in radiotoxicity studies have been found especially fruitful.

The work of the I. A. E. A. Laboratory includes a number of projects in medical physics, among which are various applications of the I. A. E. A. 's own whole-body counter, the evaluation of the performance of various instruments for medical radioisotope work and several international intercomparison and standardization programmes, for example, on the measurement of uptake of radioiodine by the thyroid gland and on the measurement of radiation dose in radioisotope teletherapy.

International symposia on many aspects of medical physics have been held by the I. A. E. A. in recent years; these include meetings on radiation dosimetry, whole-body counting, medical radioisotope scanning and radioisotope sample measurement techniques. The I. A. E. A. undertakes the collection and correlation of data concerning radiation dose in radiotherapy, operates a service providing radiation data for medical use, and also publishes a regular intervals a guide to recent literature in nuclear medicine.

The mode of operation of the I. A. E. A. will be discussed and the above activities described in detail.

G. E. Osman,
U. A. R. Atomic Energy Establishment, Cairo.

80. A PROPOSED PLAN FOR THE DEVELOPMENT OF PHYSICS AS APPLIED TO MEDICAL SCIENCES IN THE U. A. R.

In the U. A. R. a plan for a new central organization has been adopted by the U. A. R. A. E. E. who fostered the medical physics services in the country.

An organization plan for the physics services in hospitals and medical research institutes to suit developing countries is proposed. This plan includes various tables and operational diagrams.

The new medical physics division is aimed at developing into a regional training centre for the Arab States to train hospital physicists, biophysicists, radiologists, engineers and technicians.

The role of technical aid, international and inter-governmental, and a call for the efforts and experience of medical physicists of the I. C. M. P. to help to develop this field in other countries, are discussed.

COMPUTER APPLICATIONS IN THERAPY

J. L. Howarth,
University of New Mexico, Albuquerque, U. S. A.

81. APPLICATIONS OF COMPUTER TECHNIQUES TO RADIOLOGICAL PROBLEMS.

Some uses of computers in radiological problems other than dose planning will be discussed. Particular problems considered will include the calculation of dose distributions near boundaries in inhomogeneous absorbers and the construction of mathematical models for tumour growth.

R. E. Bentley,
Institute of Cancer Research, Sutton.

82. A DIGITAL COMPUTER FOR THE CALCULATION AND IMMEDIATE PRESENTATION OF DOSE DISTRIBUTIONS.

A general purpose digital computer which is small enough to be used in a hospital laboratory is now commercially available. This machine has been programmed so that isodose curves due to the superimposition of several X-ray fields may be displayed on a cathode-ray screen immediately the field arrangement has been decided upon. Dosage data for each X-ray field are stored on paper tape and entered into the computer. The position, angle of entry and weight to be given to each field are entered from a key-board. As one field is entered, a reproduction of its isodose distribution appears on the screen, at the appropriate position and angle. The combined dose distribution can be seen immediately after the input of each additional field. A large number of fixed field configurations can thus be examined in a short space of time.

Since the computer has a cycle time of only 1, 6 μsecs it is possible to produce a 4 field distribution in about 1 second. The method is contrasted with the analogue technique described by Jones and Bentley in the next paper. The possibility of a hybrid device enjoying the lower cost of the analogue systems and the greater flexibility of digital methods is discussed.

J. C. Jones and R. E. Bentley,
Royal Marsden Hospital, Sutton.

83. AN ANALOGUE COMPUTER FOR THE CALCULATION AND IMMEDIATE PRESENTATION OF DOSE DISTRIBUTIONS.

An electronic analogue computer has been designed to present isodose curves on a cathode ray screen. For supervoltage X-ray machines and Cobalt units it has been found possible to generate the dose at any point in the x-y plane by using two diode function generators and two multiplying circuits of the quarter square type.

The whole plane is scanned in about 1 second by applying cyclically varying voltages of different frequencies to the x and y inputs. The same varying voltages are applied to the x and y plates of an oscilloscope, and it is arranged that the beam brightens up when the generated value of dose reaches a predetermined level. Isodose curves in the form of a series of discreet bright points appear on the screen. The display may be shifted by biasing the x and y inputs, and rotated by modifying the x and y voltages with sine and cosine potentiometers.

By replicating this circuit, the apparatus may be extended to present the resultant dose distribution from several x-ray fields applied to the patient. Several voltages corresponding to the dose due to each field are generated simultaneously, and added in a summing circuit. It is expected that the analogue method of rapid planning will be less expensive than a comparable digital method, but will probably be less amenable to refinement and development.

J. S. Robertson,
Brookhaven National Laboratory, U. S. A.

84. COMPUTER APPLICATIONS IN SOME SPECIAL PROBLEMS OF RADIATION DOSIMETRY.

Two special radiation dosimetry problems in which digital computer methods have been useful are: the dose from tritium in cellular geometries, and the dose from neutrons in neutron capture therapy of brain tumours.

Because of the low energy and short range of the tritium β-particle, the standard methods of dose calculation are not applicable in many situations, particularly when a labelled substance which concentrates in the cell nucleus is used. The problem has been approached as follows. From the tritium β -spectrum and from range-energy relationships, the average amount of energy reaching a given distance from a point source is computed. From this function the energy that escapes from, or is absorbed in, a given geometry may be computed by numerical integration, as can the dose at any point.

Similarly, in computing the dose due to gamma-ray production in neutron exposures, the dose calculation methods that assume a uniform source distribution are not applicable without modification because of the rapid attenuation of the neutron flux with depth. This problem was approached by dividing the volume of interest (the head) into elements of volume by radial, transverse and coaxial slicing. Each element of volume is treated as a gamma source of intensity determined by the neutron flux at its centre. The dose at any point of interest is computed by integrating over the volume, taking into account the appropriate geometry, build-up, and attenuation factors for each element of volume. Comparison of the computed dose with measurements made in a tissue-equivalent cylinder shows close agreement.

J. van de Geijn,
H. Joannes de Deo Hospital, The Hague, Netherlands.

85. THE COMPUTATION OF THREE-DIMENSIONAL DOSE DISTRIBUTIONS IN ^{60}Co - TELETHERAPY.

Details were recently published in the Brit. J. Rad. of the use of a new, relatively simple theoretical model of the dose distribution produced by a rectangular beam of high energy X- or gamma-rays in a waterequivalent medium. A simple generating function can be derived by which the dose at any point in such a beam can be computed. Two computer programmes, based on this generating function, were developed, one for stationary fields and the other for moving beam techniques. In this way it is possible to compute three-dimensional dose distributions in individual patients.

The possible merits of the use of a fast digital computer on a regional or even a national scale are currently being investigated, with financial help from the Queen Wilhelmina Fund for Cancer Research.

Particulars are given about the number and the nature of both the fixed field data and the variable field data, with examples of individual problems. Details are also given about the display of the results. Finally, an idea is given of the overall costs per patient.

C. S. Hope,
Regional Physics Department, Glasgow.

86. THE APPLICATION OF COMPUTERS TO JUDGEMENT PROBLEMS IN RADIOTHERAPY.

A brief outline is given of:

(a) methods of preparing and processing field data used routinely for multified treatment planning;

(b) optimizing treatment plans by a simplification of field data, so that the computer can consider a wide range of possibilities: it can exercise judgement by selecting the best according to a compromise between the extent to which the plans satisfy several different criteria;

(c) a possible approach to the problem of selecting the best fractionation regime;

(d) diagnosis by comparison of symptoms.

An evaluation of the present and future importance of computers in radiotherapy is given in the light of experience gained with the above problems.

W. A. Jennings,
Royal Northern Hospital, London.

87. PROGRAMMED 3-DIMENSIONAL IRRADIATION.

The aim of this project is to extend confined high dose zones to irregular shapes, corresponding to the anatomical delineation of the tumour, or to its lines of spread. In practice, such treatment zones may be sinuous tracks of elliptical cross-section, - the eccentricity, orientation and dimensions of which may vary along the track. The achievement of uniform dosage over such zones entails the adaptation of an already versatile ^{60}Cobalt Unit, so that both the source-head and treatment couch form part of a co-ordinated motorized system. Further, it must be possible to programme easily the control mechanism for each patient.

Appropriate elliptical dose contours at successive patient-sections can be obtained by arc therapy in which the angular velocity and beam width vary during oscillations of the beam axis between selected reversal positions. The extension of a series of such sectional distributions along a 3D track is achieved by vertical and lateral movements of the couch-top during its translation at a variable speed along the axis of the revolving source head. Each parameter to be pre-set, or varied during treatment, is pre-calculated and expressed in the form of profiles. Combined chart-inserts of such data for each patient are employed, and photoelectric profile-followers for each movement transmit the requisite information to the Cobalt source-head and couch.

The basic dosimetric studies have been made with the aid of an Elliott computer, together with film and phantom measurements in a multi-section patient-phantom.

R. J. Shalek and M. Stovall,
M. D. Anderson Hospital & Tumor Institute, Houston, Texas, U. S. A.

88. AN EVALUATION OF RADIATION DOSE SPECIFICATION IN THE PATERSON-PARKER RADIUM SYSTEM.

There are now several methods for the calculation by computer of isodose curves around interstitial and intracavitary radiation treatments for individual patients. In order to improve the accuracy of the dose calculated, the radiation distribution from filtered linear sources has been reviewed in detail; and to aid in relating clinical experience accumulated with the Paterson-Parker system to these newer methods, a comparison has been made of the dose calculated by both methods for typical planar and volume implants.

It is concluded that the Paterson-Parker tables for linear sources are correct, if allowance is made for the change in specific gamma-ray emission, tissue absorption, and the conversion from exposure to absorbed dose. Other factors considered include the effective thickness of filter, radiation absorption in the radium salt, and the variable absorption coefficient of radium gamma-rays in platinum. For usual planar and volume implants a multiplicative factor of 0, 90 will convert the dose derived from Paterson-Parker tables into absorbed dose in rads, making allowance for the factors mentioned above and for a small correction due to oblique filtration.

DOSE DISTRIBUTION

K. A. Wright, M. I. Smedal, F. A. Salzman and J. G. Trump,
High Voltage Research Laboratory, Mass. Inst. of Techn.
and Lahey Clinic Foundation, Boston, Mass., U. S. A.

89. SYNCHRONOUS FIELD SHAPING IN MEGAVOLT X - RAY THERAPY.

Techniques involving the use of synchronously rotating absorbers for modifying the shape and distribution of the absorbed dose in typical tumour situations under 360^{o} rotational treatment with 2 MeV X-rays will be described.

The method, resultant dose distribution, and preliminary clinical appraisal of providing individual kidney protection during wide-field 360^{o} rotational treatment of the abdomen, as in disseminated cancer of the ovary, will be discussed.

The physical aspects, including field dosimetry, of spinal cord protection and eye protection during 360^{o} rotation will be correlated with clinical observations on several hundred patients.

During the past 6 years, the use of synchronously rotating protective devices and field-shaping absorbers has evolved into practical and flexible procedures applicable to routine clinical radiotherapy. These techniques, we believe, achieve more closely the desired localization of absorbed radiation energy in the tumour-bearing regions.

J. Telich, G. Castaneda and G. Garcia,
Mar Banda, Mexico.

90. DEPTH DOSE CORRECTIONS IN NON-WATER EQUIVALENT MATERIALS UTILIZING TRANSIT DOSE MEASUREMENTS.

A simplified method for transit dose measurements is described; the method utilizes an ionization chamber or film as a detector. Special emphasis has been placed on obtaining correction factors for different zones of the irradiation field. Results of laboratory tests and of clinical cases are given. The routine use of the method is also described.

P. G. Orchard and L. R. King,
Royal South Hants Hospital, Southampton.

91. THE APPLICATION OF A DECREMENT SYSTEM TO THE RAPID CONSTRUCTION OF ISODOSE CURVES AT VARIABLE S. S. D. AND OBLIQUE INCIDENCE.

A practical system for the production of ^{60}Cobalt isodose curves is described, for any condition of incidence within a wide range of selected variables. It involves the use of a simple plotting table; isodose curves can be rapidly produced by a technician, and the system has been successfully used for the routine preparation of data for an isocentric Cobalt Unit.

The Cobalt Unit works at 75 cm source-axis distance, decrement diagrams are prepared from measurements at normal incidence at two source-surface distances (60 cm and 70 cm), and central axis data for all field sizes necessary are prepared for source-surface distances at 5 cm intervals from 55 cm to 70 cm S. S. D. The presentation of the latter gives the depth of each (10% interval) isodose curve at each decrement value. Both sets of diagrams are colour coded, and are used together on a plotting table to obtain the isodose curve required, variations in surface position being allowed for by using a "0.6 times gap" correction associated with the central axis datum; the shape of the beam as defined by the decrement system is maintained in a correct relationship with the surface. Within the limits of the decrement system the accuracy of presentation of data is better than 3%.

I. Ragnhult, B. Roos and M. Cohen,
Radiophysics Institute, Gothenburg, Sweden, and I. A. E. A., Vienna.

92. A STUDY OF INTEGRAL DOSE EFFICIENCY FACTOR.

The concept of "efficiency" in radiotherapy is relatively new. ICRU Report 10d (1963) defined the Integral Dose Efficiency Factor as "The ratio of the integral dose in the target volume to the total integral dose to the patient." While the significance in radiotherapy of the integral dose as such is still controversial, there can be no doubt that, other things being equal, a high efficiency factor is advantageous. For defined tumours in actual patients the efficiency factor is easily calculated and serves as an index of the relative merits, in physical terms, of alternative treatment techniques. In the present study, however, efficiency is considered as a general problem in clinical dosimetry, with particular reference to multiple-field teletherapy using high energy photon beams.

Important preliminary considerations are: (1) the significance of the phrase "other things being equal;" (2) the effect on efficiency of the assumptions made as to the target volume or area, including its shape and size; (3) the relationship between the area (i. e. single plane) and volume efficiency factors. The derivation of the area factor by graphical and digital computer methods is described. Most of the calculations in this study were made with an ALWAC computer at the ADB-Institute, Gothenburg. Area efficiency factors have been calculated for a series of hypothetical tumours in a "patient" of defined cross-section. The first results are presented showing the dependence of efficiency on the number of fields, the field size, radiation energy, position of the "tumour" and other parameters.

X-RAYS, SPECTRA AND DIAGNOSTIC APPLICATIONS

A. D. Rotenberg and R. A. Beique,
Montreal General Hospital, Montreal, Canada.

93. A GENERALIZED SOLUTION FOR THE ATTENUATION OF BREMSSTRAHLUNG SPECTRA.

The difficulties in understanding the properties of bremsstrahlung radiation has been due to the necessity of considering individually a large number of different photon energies. A simplified approach to the problem has been found, expressing the spectral distribution and the energy-dependent attenuation coefficients in terms of functions of dimensionless variables.

The material to be presented is based on Kramer's Law describing the thick target bremsstrahlung spectra, and on an empirical relationship, describing the energy dependence of the attenuation coefficients. An equation has been derived for the intensity of an X-ray beam after attenuation by any absorber. The intensity equation consists of the product of two functions: the first comprising the energy independent variables, while the second, in the form of an integral, accounts for the energy dependent variables. The integrand can be reduced to a function of a single dimensionless variable which can be integrated numerically.

It will be shown that the intensity equation depends exclusively on four independent variables which could be the accelerating voltage and current of the x-ray tube, and the atomic composition and thickness of the absorbers. Partial derivatives of the intensity equation give the properties of the beam, for example, the effective coefficient, the differential spectrum and the change of intensity with change in accelerating voltage.

Some of these functions will be presented showing how the generalized variables can be used in the understanding of the attenuation of bremsstrahlung radiation and the physics of radiography.

P. Tothill,
Medical Physics Department, The Royal Infirmary, Edinburgh.

94. THE RATIO OF TUNGSTEN K-CHARACTERISTIC RADIATION TO CONTINUOUS RADIATION DETERMINED USING BALANCED FILTERS.

In order to use attenuation methods of estimating the spectral distribution of X-rays, it is usually necessary to make allowance for the amount of characteristic radiation present. Measurements of this parameter were made for a range of operating voltages up to 250kV,. and three different degrees of filtration, using balanced filters to isolate the K-lines from tungsten. Solutions containing erbium and ytterbium were used as filters to isolate the combined Kc_1 and Kc_2 lines. A thulium-erbium pair did so only partially, owing to the closeness of the thulium absorption edge to the Kc_1 line and the finite width of the latter. The Kc_2 line was isolated by a tantalum-hafnium pair. The filters were used in conjunction with two ionization chambers, arranged so that the difference between ionization currents was measured. It was necessary to allow for incomplete balance for the unfiltered beam, for the amount of continuous radiation within the pass band and for the transmission of the filters. The maximum proportion of K-characteristic radiation expressed in terms of exposure rate was 12%. Good agreement was found between these measurements and others using a proportional counter.

P. N. Goodwin,
The Johns Hopkins Medical Institutions, Baltimore, Maryland, U. S. A.

95. THE SPECTRAL MEASUREMENT OF HIGH VOLTAGE AND SUPERVOLTAGE X-RAYS.

Measurements have been made of the spectral distribution of X-rays in the treatment beams of various X-ray generators covering the range 100kV to 300kV, and also at 2 mV. These measurements were made by using a scintillation counter to measure the radiation scattered by a thin sheet of low-atomic number material placed in the beam at the normal FSD. The results have been used to study the effects of collimators, wedge filters, open versus closed cones, and collimating devices, and also to obtain the rads/roentgen factors for these beams. The method of measurement will be described, and the results will be presented for all normal filter combinations in the range 100 - 300 kV and at 2 mV.

S. C. Lillicrap, R. E. Bentley and J. C. Jones,
Royal Marsden Hospital, Sutton.

96. SPECTRAL DISTRIBUTION OF X-RAYS FROM HIGH VOLTAGE THERAPY MACHINES.

The problems associated with the determination of X-ray spectra from generators in use for radiotherapy are discussed, and the results of investigations using a 3" x 3" No. 1 crystal as detector, on a 2 mV Van de Graaff generator and two nominally 6 mV linear accelerators, are presented.

The chief problem lies in achieving a sufficient reduction of the number of photons entering the crystal to enable individual photon encounters to be registered. It is not usually possible to reduce the intensity of the main therapy beam without altering the spectral distribution, and the distances available in a therapy room are severely limited. The difficulty has been overcome by the use of fine collimators and by scattering the beam through a suitable angle by a sheet of aluminium. This procedure has the additional advantage of reducing the photon energy and thus making possible the use of smaller crystals.

The problem is aggravated in the case of the linear accelerators by the pulsed nature of the radiation beam. Since resolution of counts inside the radiation pulse is impossible, the counting rate has to be reduced, so that the probability of more than one count per pulse is small. This severely limits the background counting rate that can be allowed. The considerable amount of lead shielding necessary has, however, been reduced by using the shielding provided by the layout of the concrete walls at the entrance to the therapy room.

G. A. Hay,
University of Leeds, Leeds.

97. A THEORETICAL BASIS FOR THE OBJECTIVE MEASUREMENT OF X-RAY IMAGE DETECTOR PERFORMANCE.

Image degradation in X-ray image detectors has hitherto been measured by simple subjective methods. The accuracy is naturally limited by subjective variations, but this factor can be minimized by careful experimental design: such methods are being continuously developed, and we have shown them to be of considerable practical value.

The development of objective methods has been greatly retarded by the complex nature of image transfer processes, which in general include both technical and statistical (noise) factors. Considerable progress has been made for relatively simple image detectors, such as the radiographic screen-film combination, in which statistical factors are relatively unimportant: the technical limitations may in general be measured and expressed in terms of the well-known modulation transfer function. For the more complex detectors, such as image intensifier television systems, where statistical factors may predominate, there is no objective method of measurement at present available.

In the paper, a theoretical basis is suggested for comprehensive objective measurements of system performance. A particular feature of the presentation is a method, thought to be complete and rigorous, of describing the statistical deficiencies of an image. In the application of these principles, the parameters of the output image are measured and those of the corresponding input image are either measured or computed. The transfer properties of the image system are then expressed in output-to-input ratio form in terms of three principal functions:

(1) mean intensity transfer function,

(2) modulation transfer function,

(3) noise transfer function.

Brief reference will be made to work already in progress in this laboratory on the measurement of the noise transfer function.

M. Davison,
Regional Physics Department, Glasgow.

98. TELEVISION TECHNIQUES AND IMAGE QUALITY.

Closed circuit television links used in fluoroscopy or for remote viewing of radiographs are often seen to be poorly adjusted and not giving optimum performance. Two types of test are more useful for routine hospital use than are the methods previously proposed for determination of the quality of an X-ray image. The first is an elaborate investigation in terms of contrast transfer functions to give the optimum capability of any particular system. The second is the simple subjective test routinely used to prevent unnoticed deterioration which leads to lost information. Both types of test are carried out and portable instruments are being developed in the light of this experience.

A. Robinson and J. Fox,
Hammersmith Hospital, London.

99. QUANTUM NOISE AND OTHER LIMITING FACTORS IN X-RAY DIAGNOSTIC BEAMS USED TO MEASURE DYNAMIC CHANGES IN LUNG DENSITY.

An X-ray method has been developed for measuring the transient changes in lung density due to the pulsation of blood at each heartbeat, in order to estimate cardiac function without the necessity of cardiac catheterization.

A 2" diameter beam of 40 - 60 kVp X-rays is transmitted through the lung, and the intensity measured by a zinc cadmium sulphide phosphor and photomultiplier. The sensitivity and frequency response of the system have been made adequate, after a number of problems have been overcome. The limit of sensitivity is set by the shot noise due to the small number of X-ray quanta absorbed by the detector within the integrating time of the system, which must be sufficiently short to respond to cardiac frequencies. The necessary compromise will be discussed, with experimental results.

M. B. Heller,
New York University Medical Center, U. S. A.

100. A PROCEDURE FOR CALCULATION OF GONADAL X-RAY DOSE IN DIAGNOSTIC RADIOGRAPHY.

The paper presents the procedure used in calculating gonadal X-ray exposure resulting from diagnostic radiographic examinations conducted in private physicians' offices in New York City. The data collected in this study include technical and patient information relating to 47,000 radiographic exposures gathered in a sample consisting of 680 offices, each supplying data on all examinations and patients for a one month period. Since direct measurement was precluded by the nature of the sample, a unique approach was devised to calculate the gonadal dose for each exposure for the purpose of ultimately arriving at the genetically significant dose to the population.

The method is predicated on: (1) a one point calibration of each radiographic unit which includes output and H. V. L. determination; (2) a procedure which can predict output and H. V. L. at any KVP for that unit to within 3%; (3) an accurately determined set of measured gonadal doses in a realistic human phantom; and (4) a procedure for realistically modifying these doses for the anthropometric characteristics of any patient and the technical variables associated with specific examination.

The gonadal doses for certain examinations and the technical variables responsible for their excess are discussed.

S. Piermattei Ricci and A. Casnati,
C. N. E. N., Rome.

101. AN ANALYSIS OF THE ABSORPTION METHOD FOR DERIVING RADIATION SPECTRA.

Knowledge of radiation spectra is of importance in dosimetry and radiation biology. In this paper the measurement of the radiation spectra by means of absorption analysis is described. The equipment and the experimental procedure required are relatively simple and, therefore, make this method a useful supplement to standard techniques of scintillation spectrometry.

The method involves the reconstruction of the radiation spectrum from transmission data by solving a Freedholm first kind integral equation. Equations of this type can be solved by means of an integral transform. In our case the transmission data are fitted with a suitable Laplace transform and the spectrum is derived from the inverse transform. We obtained absorption curves over a range of 100% to 1% transmission, using a 300 kV X-ray apparatus under different working conditions and with different filtrations.

Our aim is to make a critical analysis of the method in order to study (1) the influence on the spectrum shape of the mode of analysis of the experimental data; (2) the modification induced on the spectrum by different choices in number and thicknesses of the absorbers, and finally (3) the minimum set of absorbers which give still good results.

The numerical calculations have been performed using a 1620 IBM computer, and the spectra have been derived for two different types of absorber. A comparison is made between theoretical spectra given by Kramer's theory and experimental data. Similar measurements are in progress to determine the thermal neutron spectrum of a channel of the RC-1 Triga Mark II reactor existing in our centre.

M. B. Heller,
New York University Medical Center, U. S. A.

100. A PROCEDURE FOR CALCULATION OF GONADAL X-RAY DOSE IN DIAGNOSTIC RADIOGRAPHY.

The paper presents the procedure used in calculating gonadal X-ray exposure resulting from diagnostic radiographic examinations conducted in private physicians' offices in New York City. The data collected in this study include technical and patient information relating to 47,000 radiographic exposures gathered in a sample consisting of 680 offices, each supplying data on all examinations and patients for a one month period. Since direct measurement was precluded by the nature of the sample, a unique approach was devised to calculate the gonadal dose for each exposure for the purpose of ultimately arriving at the genetically significant dose to the population.

The method is predicated on: (1) a one point calibration of each radiographic unit which includes output and H. V. L. determination; (2) a procedure which can predict output and H. V. L. at any KVP for that unit to within 3%; (3) an accurately determined set of measured gonadal doses in a realistic human phantom; and (4) a procedure for realistically modifying these doses for the anthropometric characteristics of any patient and the technical variables associated with specific examination.

The gonadal doses for certain examinations and the technical variables responsible for their excess are discussed.

J. R. Cameron and J. A. Sorenson,
University of Wisconsin, U. S. A.

102. IMPROVED INSTRUMENTATION FOR BONE MINERAL MEASUREMENT IN VIVO.

An improved device for the measurement of bone-mineral content has been constructed and is presently in use at the University of Wisconsin Hospitals. The photon source and scintillation detector are mounted on a turntable which is driven through a rack and gear system on its circumference. The linear scanning speed used is 0.8 mm/sec, and is easily varied by changing drive gears. The change in apparent width of the bone scan, caused by the fact that the source travels on a circular path rather than in a straight line, is less than 1% for bone diameters up to 1.5 cm. The scanning time for a bone such as the radius is about 30 sec. The photon transmission rate is continuously measured with a pulse height analyser, precision ratemeter, and potentiometric recorder.

A 35 mc ^{125}I source was constructed by an ion exchange method. This well-collimated source, of dimensions 1 mm dia. by 7 mm, gives a counting rate of about 400,000 cpm in air. A flexible rubber tube (Penrose drain) filled with a 2% solution of potassium sulfate in water, is wrapped around the arm, and flattened between Plexiglas holders to provide a constant thickness of tissue equivalent plus bone throughout a scan of the radius. In vivo scans with this improved device show standard deviations of less than 2%, and are reproducible on a daily basis to within 4%, over periods of several weeks.

G. W. Reed,
The General Infirmary, Leeds.

103. THE ASSESSMENT OF BONE MINERALIZATION FROM THE RELATIVE TRANSMISSIONS OF ^{241}Am AND ^{137}Cs RADIATIONS.

An apparatus has been constructed in which either of two finely collimated beams of radiation may be directed accurately through a selected bone in the living patient and the transmission measured with a scintillation detector and pulse analyser. The sources of radiation are of widely differing energy; the one is Americium-241 and the other Caesium-137, giving effectively monoenergetic radiation of 60 KeV and 662 KeV respectively. The absorption of the ^{241}Am radiation is particularly sensitive to atomic number and, in bone studies, is dominated by the calcium present; the absorption of the ^{137}Cs radiation is insensitive to atomic number and is determined by the mass of material in the beam. Comparison of the two transmissions thus provides a measure of the calcium in the path traversed. The use of monoenergetic radiation and the reduction of scatter to a minimum overcome many of the difficulties inherent in radiographic techniques applied to the measurement of bone mineralization.

The construction, performance and calibration of the apparatus are described and its application to clinical studies outlined. In addition to its clinical potentialities the apparatus provides a convenient and rapid method for the determination of effective atomic number (e.g. in testing the suitability of materials as phantom constituents) and its application to the in vitro study of bone specimens in various forms is also described.

B. E. Keane,
Sussex.

104. IMAGE QUALITY IN STEREOSCOPY.

The requirements for stereoscopy in medicine are reviewed in the light of existing and possible applications. Limitations imposed by image distortions, introduced during the taking and viewing processes, are discussed and methods of estimating the magnitude of these distortions in practical cases are described.

The peculiar characteristics of stereoscopy which make a rigid analysis elusive are investigated in the light of information theory, and the paradox of storing information from a volume on only two planes of limited capacity is resolved.

From these theoretical studies, practical conclusions are drawn in the form of optimized techniques for particular purposes and a guide to the choice of apparatus for medical applications of stereoscopy.

C. A. Greatorex,
Institute of Cancer Research, Sutton.

105. A FOUR CHANNEL RADIATION RADIOTELEMETRY SYSTEM.

In studies of the uptake or distribution of radioactive sources in vivo it may be advantageous in some cases to allow the subject considerable freedom of movement whilst measurements are being carried out. A telemetry system is described in which the signals derived from up to four radiation detectors may be transmitted by radio link to a receiver.

A carrier frequency of 26. 5 Mc/s is used and channel selection is obtained by means of pulse-code modulation. The information obtained from each detector is displayed on its associated strip-chart recorder.

The apparatus has been used in preliminary experiments designed to measure the transit times of food through various sections of the gut. In these experiments the subject swallowed a small Perspex sphere in which was sealed a 20 μc source of ^{57}Co. The γ-radiation from this source was detected by four Geiger counters strapped at suitable positions on the subject's abdomen, and continuous recordings were obtained of the counting-rate in each detector as the sphere passed through the alimentary tract. A comparison of the counting-rates in the different channels enabled estimates to be made of the positions of the source and of its transit time between specific points.

RADIATION BIOLOGY

C. H. Marshall,
St. Bartholomew's Hospital, London.

106. PULSED RADIOLYSIS AND FLASH SPECTROSCOPY STUDIES ON AMINO ACID SOLUTIONS.

The new 15 MeV Vickers electron accelerator at St. Bartholomew's Hospital Medical College is being applied to the problem of studying the transient chemical effects of a single pulse of radiation on amino acid solutions. A constricted air spark has been used to produce an absorption spectrum photograph of the solution shortly after the irradiation. Some details of the apparatus used will be given.

The problems involved in measuring the dose delivered by a single pulse of radiation of a few microseconds duration will be discussed. Ferrous sulphate, lithium fluoride, Perspex and secondary emission foils have been used for this purpose.

The transient absorption spectra observed in air equilibrated and deoxygenated aqueous solutions of glycine, alanine, tyrosine and tryptophan will be shown, and these results will be discussed in the context of the chemical and biological effects of radiation.

R. Oliver and B. J. Shepstone,
The United Oxford Hospitals, Oxford.

107. THEORETICAL GROWTH RATE CURVES FOR VICIA FABA ROOTS UNDER CONTINUOUS RADIATION EXPOSURE AT LOW DOSE RATE.

Using models for the meristem of Vicia faba proposed previously, theoretical curves of growth rate have been computed for conditions of continuous radiation exposure at low dose rate (1 - 10 rads/hr.) These have been compared with experimental results. The best agreement is obtained assuming cell death at the second division following radiation damage, allowing for some gradual increase in cell cycle time during irradiation, and postulating that at any rate at the lower dose rates, sterilized cells differentiate and contribute to root elongation. The match between theoretical and experimental curves suggests a value for D_o of about 240 rads for the "single hit" type of mechanism assumed to apply at these dose rates. It is predicted that if the cell cycle time is varied, similar growth rate curves should be observed for the same dose received per cell cycle (rather than for the same dose rate).

A. Halko and J. Ovadia,
Michael Reese Hospital & Medical Center, Chicago, U.S.A.

108. STUDIES OF RADIATION EFFECTS IN WATER, SALINE, AND SUSPENSIONS OF BACTERIA USING RADIOACTIVE OXYGEN - 15.

The radioactive isotope of oxygen, ^{15}O, has been used to study the incorporation of oxygen in irradiated water, saline, and E. coli 0111:B4 in saline suspension. O is produced by the reaction $^{16}O(\gamma, n)$ using 30 MeV bremsstrāhlung from an electron linear accelerator on a liquid oxygen target. The isotope is detected through its associated 0.51 MeV annihilation gamma-ray. Samples to be studied are irradiated with 15 MeV electrons (below the oxygen photoneutron threshold) immediately after ^{15}O production at dose rates of the order of 40,000 rads/min in a volume of 80 cc. The incorporation of ^{15}O in water and buffered saline was studied from 0 to 200,000 rads. It increases linearly with dose until approximately 90,000 rads and then begins to exhibit an approach to saturation at higher doses. This observation is consistent with published results on hydrogen peroxide production in irradiated water. The formation of H_2O_2 was measured by spectrophotometric observation of the oxidation of iodide ion; the relation between ^{15}O incorporation in water and H_2O_2 concentration will be discussed. The incorporation of ^{15}O in irradiated bacteria suspended in buffered saline was studied up to doses of 210,000 rads; the concentration of ^{15}O is greater in bacterial suspensions than in either water or saline, and shows no approach to saturation.

M. L. Griem and R. J. M. Fry,
Argonne National Laboratory, Argonne, Illinois, U. S. A.

109. THE EFFECTS OF IONIZING RADIATION ON THE ELONGATION AND TENSILE STRENGTH OF RODENT VIBRISSAE.

Since it has been observed that ionizing radiation causes narrowing of the hair shaft and thinning of the cortex of growing or anagen hair, it was postulated that such changes might alter the physical properties of hair as measured by elongation and tensile strength under varying load. Because symmetrically paired vibrissae show similar growth patterns, measurements were made on symmetrically paired untreated rat vibrissae which showed a like correlation in tensile strength and elongation. A pilot study was carried out as follows:

The right cheeks of rats were irradiated with acute single doses of 100 KVF X-rays (FSD 15 cm, 1 mm Al filter, 1.5 cm cone, HVL 1.35 mm Al). Graded exposures of 50 to 1500 R were used. The opposite cheek was shielded. At 250 R and above there was a decrease in the tensile strength when testing the portion of hair produced at the time of irradiation. There was an indication of a decrease in the tensile strength of hair produced one month after the single exposure of 750 R in a portion of the hair which showed no visible change. This observation is being investigated further. The use of this type of investigation in irradiation and ageing studies will be discussed.

G. Poretti,
University of Berne, Switzerland.

110. MEASUREMENTS WITH A LIQUID WHOLE BODY COUNTER OF A REPRESENTATIVE GROUP OF THE SWISS POPULATION.

The radioactive content of about 5, 500 visitors to the Swiss National Exhibition in Lausanne (April to October, 1964) has been measured with a liquid whole body counter. The content of caesium-137, potassium-40 and radium-226 was measured for two minutes, and the distribution of the activity according to sex, age and different regions of Switzerland was calculated with an IBM computer. The results show a general increase of the caesium content; typical differences in potassium content between males and demales was also detected.

Precise determinations of the radium content were not possible owing to unfavourable measurement conditions in the exhibition hall.

It is concluded that a liquid scintillation counter is a very suitable instrument for rapid and precise measurements of radioactivity in large groups of population.

J. S. Orr,
Regional Physics Department, Glasgow.

111. MEASUREMENT OF OXYGEN TENSION BY ELECTROCHEMICAL POTENTIAL.

Continuous monitoring of oxygen tension with very low consumption of oxygen is required for studies of the radiosensitivity of tissues in hyperbaric oxygenation conditions and the growth of bacteria. An investigation has been made of the possibilities of direct measurement of the electrochemical potential of oxygen electrodes under conditions in which their behaviour approaches reversibility. Useful results have been obtained both with metallic electrodes and with the Berl graphite electrode. The latter also shows a response to hydrogen peroxide which may be useful in dosimetry.

B. W. G. Morgan,
St. Bartholomew's Hospital, London.

112. OXYGEN TENSION MEASUREMENT IN NORMAL AND TUMOUR TISSUES OF THE MOUSE BREATHING VARIOUS GAS MIXTURES AT NORMAL AND ELEVATED PRESSURES.

Oxygen tension measurements have been made in mouse tissues by means of the oxygen-cathode technique. The levels found in the tissues at rest, during air breathing, are compared with those in the tissues with the animal breathing nitrogen, oxygen and carbon dioxide, oxygen or oxygen at high pressure. These results in normal tissues will be compared with those in the Ehrlich ascites tumour grown in solid form and the spontaneous mammary tumours in C_3H mice. Some of the implications of these relative tissue oxygen tension measurements will be discussed.

D. V. Cormack,
University of Saskatchewan, Canada.

113. DISTRIBUTIONS AND AVERAGE VALUES OF LINEAR ENERGY TRANSFER.

Distributions of absorbed dose as a function of LET were calculated for the following radiations: 25 MeV betatron bremsstrahlung, 2 MeV electrons, ^{60}Co gamma-rays, 250 KVP X-rays, 50 KVP X-rays, tritium beta particles and heavy ions with energies 1, 10 and 100 MeV per a. m. u. The effect on the distribution of the choice of cut-off energy is considered. For each radiation, both track-average and dose-average values of the L. E. T. were calculated. The determination of an "effective" LET for use in the analysis of RBE studies will be discussed.

ULTRASONIC AND OPTICAL TECHNIQUES

J. A. Newell,
Queen Elizabeth Hospital, Birmingham.

114. PHYSICAL LIMITS IN ULTRASONICS: FOCUSING AND RESOLUTION.

The wave nature of ultrasonics limits the degree of focusing and the resolution that can be achieved. The limit in dimensions of the focal area and in resolution are both of the order of a wavelength. The wavelength can, of course, be reduced by increasing the frequency. However, ultrasonic absorption in biological tissue increases approximately linearly with increasing frequency.. This places a practical limit to the increase in frequency that can be tolerated. When focusing ultrasonics for treatment, there must still be left a workable gain in intensity in the focal area. When propagating pulses of ultrasonics through tissue for locating interfaces, the returning echo pulses must be detectable above noise. The limit in size of the focal area, and the limit of resolution, can both be expressed in terms of the frequency coefficient of absorption and the depth at which focusing or location are required. This is a physical limit independent of apparatus.

A. Sokollu and E. W. Purnell,
Western Reserve University, Cleveland, Ohio, U. S. A.

115. ABSOLUTE MEASUREMENT OF TOTAL RADIATED POWER OF ULTRASONIC TRANSDUCERS FOR BIOMEDICAL USE.

A calorimetric device with proper acoustical match has been designed to measure total ultrasonic radiation emerging from a narrow orifice of a medical power-transducer. It contains a pair of thermocouples and a stirrer, providing averaged temperature readings. After irradiation, a cooling system returns the calorimeter to the starting temperature. A built-in electrical unit supplying energy to a heating element placed close to the irradiation point allows the calorimeter to be heated.

This energy measured electrically permits calculation of the radiated ultrasonic power within an accuracy of 4%.

J. McKie,
Regional Physics Department, Glasgow.

116. IMPROVEMENTS IN ORTHOPTIC EQUIPMENT.

Amplyopia is treated in young children by simple procedures such as occlusion of an eye, after removal of the causative squint or refraction defect. Difficulty is experienced when the eccentric fixation persists into later childhood or maturity. Foveal vision may be restored by exercise, if the patient is made conscious of the direction associated with foveal vision. This can be done in the clinic by means of an after-image. It may be achieved more readily by using the phenomenon of Haidinger's Brushes - the recognition in the fovea of the direction of the electric vector of plane-polarized blue light. Although a satisfactory physiological explanation of the phenomenon is lacking, the practical use requires very simple equipment. Light of wavelength less than 4, 900 A is used, and the plane of polarization slowly rotated. Apparatus loaned to the patient employs Polaroid discs rotating in an eyepiece. For group therapy, pictures are projected on to a metalized screen through a rotating polarizer. Other applications of technology to devices used in the re-training programme allow training sessions to be increased by reducing boredom and obviating the need for the continuous attention of an Orthoptist.

F. G. Parsons,
Technical Operations Research, Burlington, Mass., U. S. A.

117. MEDICAL APPLICATIONS OF ISO-PHOTOMETRY.

The analysis of radiographs, photographs, and other records on which information is stored in a continuous-tone, two-dimensional optical density pattern can often be aided by reconstructing the record as an isodensity contour plot. Such plots, which we have produced with the Tech-Ops/Joyce-Loebl scanning iso-photometer, not only present the "photometric" information contained in the record in a directly useful, scaled, and quantitative format, but also improve the accuracy of "photogrammetric" measurements on objects with diffuse edges. In addition, scanning slit size and contour interval step can be varied to suppress film grain and enhance contrast, thereby improving detection of low-contrast features. Applications of isodensity-tracing techniques to medical research and diagnosis include production of plots showing lines of constant X-ray absorption (for measurement of material densities or thicknesses); generation of takeup contours of substances containing radioactive tracers, from autoradiographs; three-dimensional measurements of cell dimensions, from birefringence microphotographs; detection of several types of low-contrast inclusions on radiographs; accurate determination of the sizes and shapes of diffuse-edged structures on electron micrographs; highly accurate location of the centre of X-ray and electron diffraction spots, electrophoresis spots, and spectral lines, and measurement of structure in those records; and production of contour lines of equal isotope takeup by body organs (from photographically-recording gamma-ray scanners) and surface temperature (from thermograph records). Examples of these applications are shown and discussed.

PAPERS RECEIVED AFTER COMPLETION OF PROGRAMME

The following papers have not been included in the programme, mainly because of late arrival. They will be read at the Conference, if time permits; details will be given on the notice board near the registration office in the Lounge Hall.

G. L. Brownell,
Massachusetts, U. S. A.

1. MONTE CARLO CALCULATION OF GAMMA-RAY DOSE.

A Monte Carlo programme has been prepared for the calculation of absorbed dose delivered by point sources and distributed sources of gamma-emitters in a tissue equivalent phantom. The basic programme traces the path of gamma-rays through an infinite tissue-like medium, recording location and energy transfer of each interaction on magnetic tape. Tape records containing 40, 000 to 60, 000 gamma-ray histories for various gamma-ray energies are used as the input data for a programme which determines energy absorption in various phantom geometries. The results are presented in terms of absorbed fraction, which is defined as the fraction of energy emitted by the gamma-ray source which is absorbed in the phantom.

Monte Carlo calculations extending the work described in previous reports will be discussed and results presented. In particular, the application of this type of calculation to ICRP recommendations will be discussed.

G. Poretti,
University of Berne, Switzerland.

2. SOME MEASUREMENTS WITH A POSITRON SCANNER.

A positron scanner for lateral and frontal measurements of the head is described, and some results are given of phantom measurements with the positron emitters ^{64}Cu and ^{74}As. Pulses from the coincidence unit are registered on a tape recorder and scintigrams are made on a photographic film. To improve the contrast of the scintigrams the number of pulses from the patient can be artificially increased in proportion to the pulse frequency; the multiplication factor can be varied.

H. Hart,
New York, U.S.A.

3. THEORETICAL RESOLUTION OF FOCUSING COLLIMATOR COINCIDENCE SCANNING SYSTEMS.

The maximal resolution of various idealized types of scanning systems will be evaluated. If N is the number of collimator channels and $N\lambda$, the detection efficiency of a focally emitted gamma-ray, it will be shown that the resolution obtainable using focusing collimator coincidence scanning (F.C.C.S.) is $\sqrt{\frac{N^2\lambda}{2}}$ times the standard single gamma resolution.

For large solid angle and large N, F.C.C.S. detection systems may, therefore, result in a significant improvement in scanning resolution. Practical considerations in equipment design and isotope selection will be indicated.

V. K. Vransky, K. Dascalov and L. Saeva,
Sofia, Bulgaria.

4. A SPECIALIZED ELECTRONIC COMPUTER FOR AUTOMATIC DIFFERENTIAL DIAGNOSIS OF TOXIC DISEASES.

Many diseases caused by toxic substances present a great variety of symptoms, and rapid and accurate diagnosis may be decisive for the treatment and its outcome.

In order to accelerate diagnosis and improve accuracy, an electronic hybrid diagnosing apparatus has been built. Information concerning the various toxic diseases and their symptoms is stored in a diode-resistor matrix. On the basis of preliminary statistical data 247 symptoms of 100 diseases have been stored. The information is fed into the computer by a push-button board. Simultaneously a card is being punched, which can be used later as an objective document. Within a few seconds the physician receives back a list of those diseases stored in the matrix, of which a given percentage of the symptoms is covered by the input symptoms.

Thus the computer can be considered as a very fast consultant-assistant which helps the physician in the diagnosis.

J. R. Cameron,
University of Wisconsin, Madison, Wisconsin.

5. THERMOLUMINESCENT DOSIMETRY.

The general characteristics of TLD will be presented and the following specific topics will be discussed.

Basic Mechanisms: 1) Sensitivity of LiF as a function of dose. 2) A mathematical model that fits the experimental data for LiF. 3) Variation of sensitivity due to pre-radiation annealing. 4) Loss of stored thermoluminescence during iso-thermal annealing. 5) Determination of energy and frequency factors of the electron traps. 6) Energy dependence of LiF and Al_2O_3.

Applications: 1) Determination of radiation quality by the paired TLD system using LiF and Al_2O_3. 2) Measurement of the absorption and build-up factors for radium, ^{60}Co and ^{137}Cs. 3) Measurement of the radiation distribution around radium needles with small single crystals of LiF. 4) Use of single LiF crystals for personnel monitoring. 5) Dose evaluation in clinical studies.

W. L. McLaughlin,
National Bureau of Standards, Washington, D. C., U. S. A.

6. HIGH RESOLUTION DOSE-DISTRIBUTION MEASUREMENT AT PHANTOM INTERFACES.

The radiation colouring of dye-cyanides in solid solution with gelatin or plastic has been found to have unique capabilities for visualization and measurement of megarad dose-distributions on a microscopic scale. Applications of these systems in radiation processing have already been suggested, since the material is essentially water-equivalent, highly stable, light-insensitive, and can be incorporated in a number of materials. The suggestion now is that, although the system requires relatively large doses for colouration (10^5 to 10^8 rads), there are potential medical applications in the measurement of dose-distributions close to interfaces of different tissue phantoms. Colourless triphenylmethane dye cyanides, such as pararosaniline nitrile, formylviolet nitrile, etc. take on very deep colours upon irradiation with G-values of the order of 10^2 to 10^3, depending on the dye. Since their solid solutions in gelatin are molecular in structure they form high-resolution grainless images. Measurement of density gradients by means of suitable microdensitometric tracings provides a convenient record of dose variations within distances from interfaces of the order of microns.

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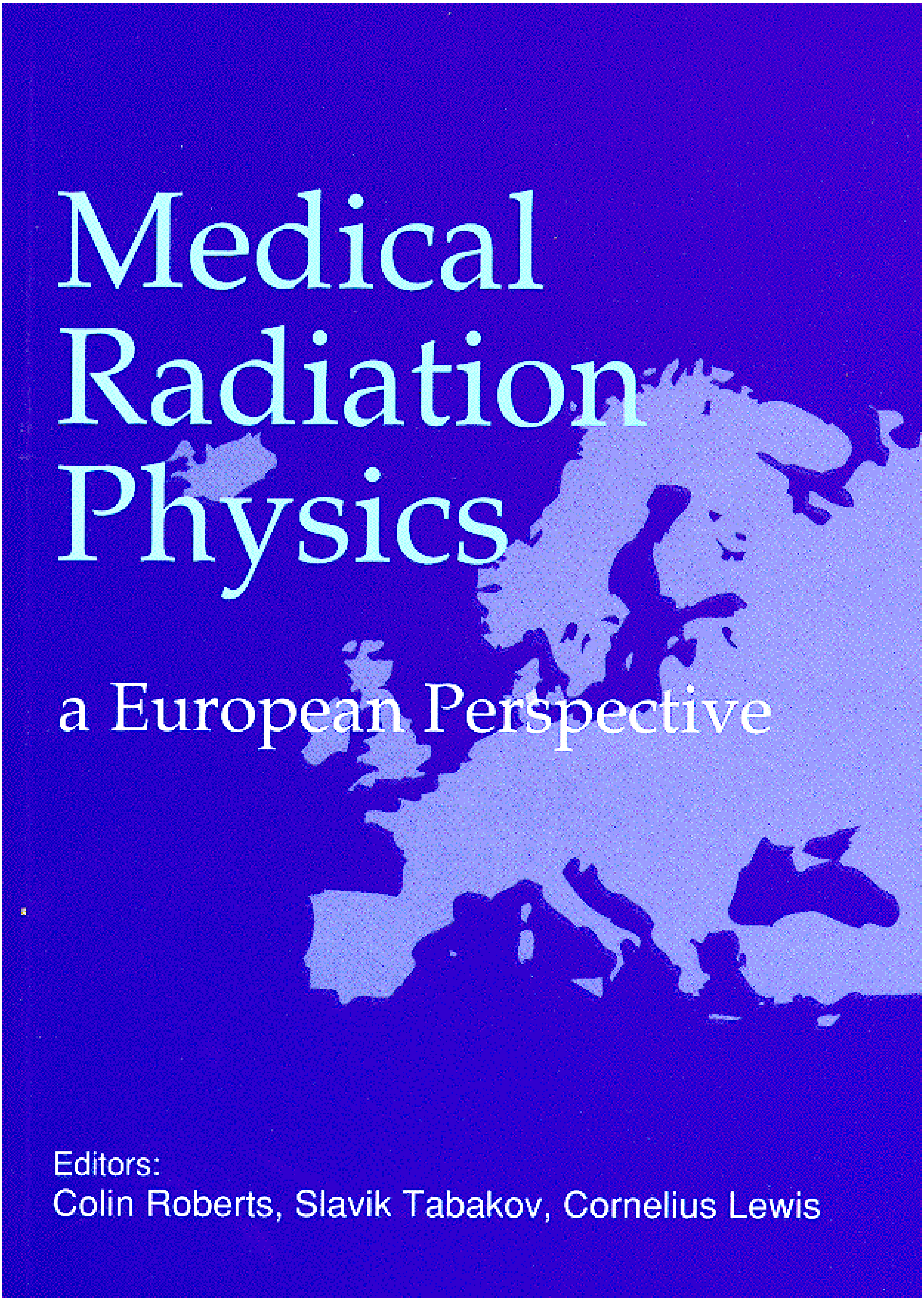
Medical
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a European Perspective
Editors:
Colin Roberts, Slavik Tabakov, Cornelius Lewis

1995

The printing of this book is funded by the Commission of the European Communities (CEC) under its activities for Cooperation in Science and Technology with Central and Eastern Europe. The preparation of the book is a phase of the CEC Project CIPA 3510 CT 92 2623 "European Conference on Post-graduate Education in Medical Radiation Physics".

Organiser of the Conference is the Department of Medical Engineering and Physics, King's College School of Medicine and Dentistry, London, represented by Professor V. Colin Roberts and Dr Slavik D. Tabakov (Project Co-ordinator).

The contributions to the book were collected with the active involvement of the European Federation of Organisations for Medical Physics (EFOMP).

MEDICAL RADIATION PHYSICS
A European Perspective

Based on the contributions to the European Conference on
Post-Graduate Education in Medical Radiation Physics,
Budapest 12-14 November 1994

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Participants to the European Conference on Post-Graduate Education in Medical Radiation Physics, Budapest 12-14 November 1994

FOREWORD
TO THE INTERNET E-EDITION OF THE BOOK

The First European Conference on Post-graduate Education in Medical Radiation Physics, held in Budapest on 12-14 November 1994 was a milestone for the development of the profession in Central and Eastern Europe and also triggered various international activities in the field.

Hundreds of copies of the *"blue book"*, which second Internet-edition is presented here, were distributed all over Europe and other countries in the world. Based on this book more than 10 new post-graduate courses in Medical Physics were initiated in various East European countries. Additionally, members of the Network formed after the Conference developed and introduced a number of international projects in education and training. The first meeting of the Network was in Krakow, Poland (satellite to the 10th Polish Congress on Medical Physics).

The international (European) projects on Education and Training in Medical Physics and Medical Engineering, developed after 1994 will be briefly described below (in chronological order).

1995 - members of the Network introduced the European Tempus Project ERM, whose objective was the development, in Bulgaria, of a one-year post-graduate MSc course in Medical Radiation Physics and Engineering. The project partners were: three Bulgarian Universities – the Medical University VMI - Plovdiv, the Technical University – br. Plovdiv and the University of Plovdiv, King's College London (Project Contractor and Co-ordinator), the University of Florence and the University of Dublin. In 3 years the project established an Inter-University Medical Physics Centre (IUC) in Plovdiv, Bulgaria and developed a successful MSc course (launched in 1997), which was later accredited by the UK's IPEM. The whole education in the IUC is in English and modularised in order to facilitate the attendance of eminent lecturers from various Universities throughout Europe. The books with Lecture Notes produced for the MSc course in Plovdiv were printed, by a specially established Foundation, for distribution to other countries. More information about this MSc course can be found at www.kcl.ac.uk/erm and www.erm.dir.bg

1996 - The needs for harmonised European training in Medical Radiation Physics were addressed through an EC Leonardo da Vinci pilot project, prepared by a Consortium of Universities and Hospitals from UK, Sweden, Italy and Portugal: King’s College London (Contrcator and Co-ordinator), the University of Lund, the University of Florence, King’s College Hospital, Lund University Hospital, Florence University Hospital, the Portuguese Oncological Institute and the International Centre for Theoretical Physics in Trieste. The objective of this project (EMERALD - **E**uropean **Me**dical **Ra**diation **L**earning **D**evelopment) was to develop a Framework of three training modules in Medical Radiation Physics (Physics of : X-ray Diagnostic Radiology; Nuclear Medicine; Radiotherapy). These modules are for the training of young graduates and post-graduate students in medical physics. The project produced structured training timetables and syllabi, Course Guide, 3 Student Workbooks and 3 CD-ROMs with Image Databases. During 1998 EMERALD Consortium organised the First European Conference on Medical Physics Training in ICTP, Triest, Italy (24-25 September 1998). More information about the EMERALD training materials and scheme can be found at www.emerald2.net

1997 – the project TEMPERE (Training and Education in Medical Physics and Engineering Reformation in Europe) was initiated. The project involved a network of professionals and professional bodies in the fields of Medical Physics and Biomedical Engineering from 16 EU countries (with University of Patras as Contractor and Co-ordinator). The project aimed to provide a forum for productive interaction among professionals on the relevant professional issues, which would lead to a proposal for a European framework for mutual co-operation and recognition in the above fields. The project developed guidelines for education and training courses and for their accreditation. A book with project results is in print at the moment. More information about the TEMPERE project can be found at http://etros1.vub.ac.be/tempere

1998 - based on the experience from the project ERM another European Tempus Project was developed aiming to establish Joint Baltic MSc courses in Medical Physics and Biomedical Engineering. The partners in this project were the University of Linkoping (Contractor), King's College London, Riga Technical University (Co-ordinator), the University of Latvia, Tallinn Technical University, the University of Tartu and Kaunas University of Technology. The launch of the MSc course, organised between the 3 Baltic states (Estonia, Latvia, Lithuania) was in 2000. The project published all syllabi of this joint modular course in the book *Baltic Biomedical Engineering and Physics MSc Courses*

(ISBN 9984 681 52 1). More information about this project and course can be found at www.rtu.lv/fakult_lapas/mzf/eemti/BaltTemp.html

1999 - A second EU Leonardo project - *EMERALD Internet Issue* (EMERALD II) - was initiated by the EMERALD Consortium with additional partners from France, Ireland, North Ireland, Czech Republic and Bulgaria. The project aimed at the development of EMERALD training materials for Internet distribution. The project developed 3 sets of Web-based materials (available also on CD-ROMs). A demo is presented at the EMERALD web site. A number of International Seminars on Medical Physics training were organised in the wramework of this project: Dublin, Ireland (25-26 February 2000); Lille, France (17-18 June 2000); Prague, Czech Republic (3-5 September 2000); Lisbon, Portugal (20-22 November 2000); Lund, Sweden (19-20 January 2001) and London, UK (16-17 March 2001). At the moment the EMERALD training materials are used in more than 40 countries around the world.

Most of these activities were supported by the respective national societies, the European Federation of Organisations for Medical Physics (EFOMP) and the International Organisation for Medical Physics (IOMP). During (and after) the above seminars (2000-2001) new materials were gathered to be e-published in a new "blue book" with working title - *Medical Radiation Physics – A European Perspective UPDATE 2001*. This new electronic book will soon be available from the web site of EMERALD: www.emerald2.net

Additional materials to this new e-book from other countries are welcome Please send these as attached MS Word files to slavik.tabakov@kcl.ac.uk

August 2001, London

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INTRODUCTION

The idea for an East/West European discussion on Education in Medical Physics and Engineering has a long history. Many of the Western European countries have discussed within the European Federation of Organisations for Medical Physics (EFOMP) activities for harmonising the professional training and education, these being reflected in the Policy Statements of EFOMP. At the same time the countries from Central/Eastern Europe have had mutual agreements in the field of education, but due to the small number of professionals working in Medical Physics & Engineering, these specialities have not been addressed. Contacts between East and Western Europe in the area of education were rare before 1989. The collaborative activities which occurred after the catastrophe in Chernobil in 1986 showed that effective results can be achieved with joint endeavours.

In the field of Medical Physics & Engineering the first and most important step towards a true joint effort is the harmonisation of education and training. The necessity for a pan-European forum on these questions has been discussed on various occasions including the 5th Conference of the Bulgarian Society for Biomedical Physics and Engineering held in Sofia in 1988; the 5th Mediterranean Conference on Medical and Biological Engineering held in Patras Greece in 1989; and the Weimar Clinical Engineering Workshop in the former GDR which was held in 1990. During the International Federation for Medical & Biological Engineering (IFMBE) Intra-European Biomedical Engineering Workshop held in Szentendre, Hungary in 1991, it was agreed that there is considerable interest in and need for future collaboration between Central/ Eastern and Western European countries in the area of the professional training, and activities for a joint venture were initiated. As a result of this a submission was made successfully to the CEC for support towards the First European Conference on Education in Medical Radiation Physics.

THE EUROPEAN CONFERENCE ON POST-GRADUATE EDUCATION IN MEDICAL RADIATION PHYSICS, BUDAPEST'94

The objectives of the Conference were:

- To increase the East/West European co-operation in the field of Medical Physics;
- To establish the status and needs of education and training in Medical Radiation Physics in Central/Eastern European countries;
- To formulate proposals for the advancement of post-graduate education in Medical Radiation Physics and identify resource sharing initiatives;

- To consider the need for a Training Authority and a professional network in the field of Medical Physics & Engineering in Central/Eastern Europe.

The Organising Committee was set up in London with members:
Prof. V. Colin Roberts, Chairman,
Dr Slavik D. Tabakov, Secretary,
Dr Cornelius A. Lewis, Treasurer.
The Local Organising Committee was set up in Budapest with members:
Prof. Pal Zarand, Chairman,
Dr Nandor Richter,
Dr Istvan Polgar.

EFOMP was closely involved in the organisation of the conference the concept of which was received enthusiastically in almost all countries invited to participate. This showed once again the enthusiasm of all colleagues for collaboration. The delegates to the conference were senior professionals in Diagnostic Radiology (Roentgenology), Radiotherapy, Nuclear Medicine, Radiation Safety and Imaging, each delegate being a nominee of their European professional society and/or their University. In total 37 Institutions, Societies and Universities from 23 European countries were represented at the Conference, the majority of the delegates being active members and officials of EFOMP or the IFMBE.

The European Conference on Post-graduate Education in Medical Radiation Physics was held in Budapest from 12-14 November 1994. It was opened by Prof P. Vittay, representing the Hungarian Minister of Welfare Dr Pal Kovacs. An initial overview was presented by the Secretary General of EFOMP, Dr W. Seelentag. This was followed by presentations of the institutions and countries on the present status of medical physics education and training in their respective countries. Two general discussions (round tables) followed which focused on two major themes:

- education and accreditation of centres for education & training;
- training and continuing professional development.

The conclusions and decisions of the round tables were approved in the final plenary discussions where it was agreed that a pan-European Network should be formed and that five Working Groups should be organised to examine the following subjects:

- syllabus for education schemes;

- minimum requirements for education centres (accreditation and assessment);
- syllabus for training schemes;
- minimum requirements for training centres (accreditation and audit);
- terminology and interpretation of EU Legislation.

Details of these are printed at the end of the book together with the ***Declaration of Intent*** signed by all the delegates to the Conference.

The potential contribution of the conference to the further development of the education in Medical Physics & Engineering, its harmonisation, and the potential for intra-European collaboration in Medical Radiation Physics was highly appreciated by the delegates. It was decided at the Conference that a post-conference book should be produced to include papers from as many European countries as possible. This has been achieved with the help of EFOMP and the prompt answers of colleagues from additional European countries to our request for contributions.

Several previously published documents provide interesting background information to the subject of this book and are commended to the reader. These include the materials from the 1st IAEA/WHO seminar on the education and training of medical physicists which was held in Kiel, Germany in 1972, the policy statements of EFOMP and the IPSM Training Scheme Prospectus.

This present book *Medical Radiation Physics - A European Perspective*, contains data covering the Medical Radiation Physics support to more than 90% of the population of the European continent. We believe that it is an appropriate contribution to the world celebration of the 100th anniversary of the discovery of X-rays by W.K. Roentgen. We hope that it will facilitate an increase in the professional contacts and collaboration within a wider Europe. We also hope that the strong wish of all Professional Societies involved in the Project to hold subsequent conferences on these topics will be realised.

ACKNOWLEDGEMENTS

The editors of this book and the organisers of the conference would wish to express our sincere gratitude to all colleagues who gave their time and enthusiasm to ensure the success of the European Conference and the contributions from which this book has been prepared. In particular, we would acknowledge the help received from Dr K.A .Jessen, President of EFOMP; Dr P.P. Dendy, immediate Past President of the UK's IPSM and former chairman of the ETP Committee of EFOMP; Dr A. Benini, Division of Nuclear Safety of IAEA; Dr W. Seelentag, Secretary General of EFOMP; Dr I.-L. Lamm, Chairman of ETP Committee of EFOMP; Dr G.Hanson, WHO; Dr O. Chomicki, Secretary General of Foundation Maria Sklodowska-Curie and Councillor of the International Organisation for Medical Physics (IOMP).

Special gratitude has to be expressed to Dr V. Tabakova and Mrs E. Langford for their most valuable contribution in all phases of the Project. We would also like to thank our colleagues from King's College London: Mrs J. Walker, Mrs N. Pierson, Miss T. Sullivan and especially Miss D. Smith for their secretarial support in the preparation of the Proceedings of the Conference, as well as to Mrs G. Barry for her advice. We are also grateful to SIEMENS and VARIAN for supporting some activities during the Conference. Last but not least we are grateful to the officers of CEC DGXII/B/Contracts in Brussels for their helpful advice throughout the realization of this Project and to the Commission of the European Communities for the financial support.

The Organiser
London, February 1995

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Medical Radiation Physics

OPENING ADDRESS

P. VITTAY [(1)]

"Ladies and Gentlemen,

Doctor Pal Kovacs, Minister of Welfare had conferred upon me the honour to address and open, on his behalf, the European Conference on Postgraduate Education in Medical Radiation Physics.

It is my particular honour to welcome, on behalf of the Minister of Welfare as well as on my own behalf, Mr Seelentag and Ms Lamm, who represent EFOMP, Mr Roberts representing the IFMBE and Mrs Benini, who is with us today on behalf of the IAEA.

The fact that the Commission of the European Communities (activity for Co-operation in Science and Technology with Central and Eastern Europe) is holding this meeting in Hungary is an important event for us and is seen as the acknowledgement of this country's efforts.

During her history, Hungary drove back many attacks that came from the East and endangered Western Europe. Thus, the role that Hungary had in history was that of a stronghold for Western Europe. On the other hand, it is also our historical role to be a bridge that unites, a link between the cultures of the West and the East.

Medicine and health care have been increasingly dependent on technology for decades. This technology-dependency can be seen to the greatest extent in the field of Radiology, in terms of both diagnostic procedures and radiation therapy. This implies also that the efficient and safe operation of the extremely sophisticated and complicated equipment and machines requires the contribution of specially qualified personnel, namely of physicists and engineers. Although this requirement was recognised, in theory, quite some time ago, in practical life physicists, technicians and engineers do not enjoy the same level of appreciation as do doctors.

Therefore, if I have just referred to Hungary's role as a bridge, in addition to her being a bulwark, then continuing along these lines, I can now safely say that this Conference has a bridging role between doctors and physicists-engineers on the one hand, and between the medical and technical ways of thinking, on the other. One of the major expectations

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from this European Conference is to formulate, in line with the European ideal, a common platform for clinical physicists and engineers working in hospitals who, through their training and post graduate education, would create a pool of qualified experts with interchangeable skills.

Another important aspect of the bridging role that the present Conference has to play is to promote the idea that clinical physicists and engineers may enjoy moral and financial esteem, as well as opportunities for professional careers that derive from the responsibility they have to shoulder that are equal to, and are at the same level as those of medical doctors.

We know that we are far from this situation all over the world and that today, it is a sense of vocation rather than financial interests that drive physicists and engineers towards the health services. In spite of this, we must do our best and make efforts to the end that, while maintaining the sense of vocation, moral and financial remuneration should also fall to the lot of these enthusiastic people.

Ladies and Gentlemen,

May I conclude by wishing every success to all the participants of this Conference on behalf of Minister Pal Kovacs and on my own behalf. Herewith, I declare the European Conference on Post-graduate Education in Medical Radiation Physics open".

(1) Professor Pal Vittay, Director General, National Institute for Radiology and Radiation Physics, H-1135 Budapest, HUNGARY.

RADIATION PROTECTION ACTIONS OF THE CEC IN THE FIELD OF RADIATION PROTECTION AND QUALITY ASSURANCE IN DIAGNOSTIC RADIOLOGY

H. SCHIBILLA [(1)]

These actions follow the requirements of the EURATOM Treaty concerning the establishment and up-dating of safety standards for the health protection of the general public and workers against the dangers arising from ionising radiation. It also covers the study of adequate preventive and protective measures.

The main purpose is the reduction of population exposure from man-made sources, of which the medical use of ionising radiation and radionuclides constitutes about 80% of that exposure.

A special EURATOM Directive has been issued, laying down basic measures for the radiation protection of persons undergoing medical examination or treatment. It requires justification of the use of ionising radiation, to keep doses as low as reasonably achievable, to give adequate training to the medical and auxiliary staff involved and to assure periodic surveillance of all equipment.

The CEC Radiation Protection Actions, therefore, concentrate special efforts on:

I. Study and implementation of measures for the optimisation of radiation protection in medicine.
II. Education and training of radiation protection principles and their practical implementation

Specific topics on which the CEC Actions are providing scientific advice and guidance with a view to harmonising and standardisation are:

I OPTIMISATION OF RADIATION PROTECTION MEASURES

I.1. Establishment of quality criteria for radiographic images and equipment functioning, with reference to good imaging performance: image detail detectability and patient reference dose levels.

I.2 Optimisation of equipment functioning by quality control measures.

I.3 Development of knowledge based systems for the selection of the optimum intervention during quality control measures.

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I.4 Establishment of European protocols for quality assurance and quality control, eg Mammography.

I.5 Dose measurement protocols.

II EDUCATION AND TRAINING

II.1 Organisation of training courses on the most recent state of knowledge in specific areas, addressed mainly to teachers and those in control of radiation protection, taking into account the varied background levels of persons to be trained.

II.2 Preparation of training programmes and training packages (including audio-visual material).

II.3 Promotion of participation of young professionals in training courses, workshops and seminars

A list of the documents prepared by the CEC Radiation Protection Actions on Quality Assurance and Radiation Protection in Diagnostic Radiology is given in Appendix 1.

RESEARCH PERSPECTIVES IN THE FIELD OF RADIATION PROTECTION AND QUALITY ASSURANCE IN DIAGNOSIC RADIOLOGY

Since the medical use of ionising radiation is generally increasing in the European Union, due to newly introduced techniques and procedures, the implementation of the EC Directive on Radiation Protection of the Patient requires more specific research work in order to establish scientifically-based guidance and training. The revision of this Directive might become another consequence of the changing situation in diagnostic radiology and of the new level of the quality and safety culture in the medical field.

Optimisation of radiation protection in medicine should now be approached by quantitative methods defining the link between the required diagnostic information and the exposure of the patient. The appropriate parameters have to be studied and the correlation between patient dose, radiological and technical procedures and the image quality must be established.

The quality criteria concept has been shown to be a valuable tool for describing image quality and the corresponding technical parameters. The implementation of the quality criteria will make the involved medical and technical staff aware of the possibilities for optimising the use of the diagnostic procedures and techniques, which will simultaneously contribute to avoid unnecessary patient exposure. The quality criteria concept has to be refined on close co-operation with the medical and technical staff so that the framework will be established for objectively evaluating the diagnostic image quality for a given dose.

The impact of the use of optimisation measures has to be assessed on the day to day practise for specific types of examination associated with relatively large individual doses or height frequency. Special attention should be given to paediatric radiology, with regard to paediatric radiology, with regard to the risk from exposure to ionising radiation which is about 2 times higher than for adults under comparable circumstances.

More thought should be given to the elaboration of quantities for risk assessment related to patient protection and referral criteria for the selection of adequate techniques and procedures.

The new research tasks will contribute to also establish a scientific basis for computer aided developments in quality assurance to the diagnostic radiological procedure. This could, at the same time, promote a closer link between the user and the manufacturer of the medical equipment involving ionising radiation, since the quality control of the installations, including certain measures for radiation protection can become an integral part of of the imaging process. Further research work should also be encouraged with a view to look for technical developments with a potential of optimising the detection and interpretation of X-rays for diagnostic purposes..

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APPENDIX 1

Documents prepared by the CEC Radiation Protection Actions on Quality Assurance and Radiation Protection in Diagnostic Radiology:

1 Drexler G, Eriskat H and Schibilla H (eds) (1981). Patient exposure to radiation in medical X-rays - possibilities for dose reduction. Proceedings of the seminar organised jointly by the CEC and the Gesellschaft fur Strahlen und Umweltforchung , Munich - Neuherberg (FRG) 27-30 April 1981. **Report EUR 7438 EN 1981**, 470pp.

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2 Drexler G, Eriskat H and Schibilla H (eds) (1985). Criteria and methods for Quality Assurance in Medical Xray Diagnosis. Proceeding of a Scientific Seminar organised jointly by the CEC and the Centre di Ricerca Applicate e Documentazione, Udine, (1) 17-19 April 1984. **Report EUR 9255 EN 1985,BJR Supplement No. 18**, 179pp.

3 Moores BM, Stieve FE, Eriskat H and Schibilla H. (eds) (1989). Technical and Physical Parameters for Quality Assurance in Medical Diagnostic Radiology: Tolerance, Limiting Values and Appropriate Measuring Methods. Proceedings of a Workshop. **Report EUR 11620, EN 1989, BIR Report 18**, 165pp.

4 Moores BM, Wall B, Eriskat H and Schibilla H. (eds) (1988). Optimization of Image Quality and Patient Exposure in Diagnostic Radiology. Proceedings of a Workshop organised jointly by the CEC and the National Radiological Protection Board - Chilton held in Oxford. (UK), 27-29 September 1988. **Report EUR 11842 EN BIR Report 20**, 288pp.

5 Fitzgerald M, and Courades JM. (eds) (1990) Medical Radiation Protection Practice within the CEC. Proceedings of a meeting organised jointly by the CEC and the British Institute of Radiology, held in London (UK). **BIR, London: ISBN 0905749 26 X**. 53pp.

6 Kramer HM, and Schnuer K. (eds) (1992). Dosimetry in Diagnostic Radiology. Proceedings of the Seminar jointly organised by the CEC, the Physikalisch - Technische Bundesanstalt, Braunschweig (FRG) the World Health Organisation and the International Commission on Radiation Units and Measurements held in Luxembourg (L) 19-21 March 1991. **Report EUR 14180 EN 1991, Radiation Protection Dosimetry.** ***43***, 1-4.

7 Busch HP, and Georgi M (eds). (1992). Digital Radiography: Quality Assurance and Radiation Protection Proceedings of the Workshop jointly organised by the CEC, the Klinikum Mannheim and the European Association of Radiology, held in Mannheim (FRG) May 1992. **Schnetztor-Verlag GmbH, Konstanz, EN 1992**. 103pp.

8 Moores BM, Petoussi N, Schibilla H, Teunen D (eds). (1992). Test Phantoms and Optimisation in Diagnostic Radiology and Nuclear Medicine. Proceedings of the Workshop jointly organised by the CEC, the Forschungszentrum fur Umwelt and Gesundheit, Neuherberg (FRG), the International Commission of Radiation Units and Measurements and the

European Federation of Organisations for Medical Physics, held in Wurzburg (FRG) June 1992. **Report EUR 14767 EN 1992, Radiation Protection Dosimetry,** *49,* 1-3.

9 Maccia C, Moores BM, Nahrstedt U, Radovani R, Wall B. (1988). CEC Quality Criteria for Diagnostic Radiographic Images and Patient Exposure Trial. **Report EUR 12957 EN 1990,** 131pp.

10 Quality Criteria for Diagnostic Images. Working Document, 2nd Edition June 1990 . **CEC XII/173/90,** EN, DA, DE, ES, FR, GR, IT, NL, PO.

11 Quality Criteria for Diagnostic Radiographic Images in Paediatrics. Working Document, June 1992. **CEC XII/307/91,** EN, DA, DE, ES, FR, GR, IT, NL, PO.

12 European Guidelines for Quality Assurance in Mammography Screening + Appendix. European Protocol for the Quality Control of the Technical Aspects of Mammography Screening. Working documents of "Europe Against Cancer" and the "Radiation Protection Actions" October 1992 **CEC V/775/92, Report EUR 14821,** EN DA, DE, ES, FR, GR, IT, NL, PO.

13 Contento G, Wall B, Schibilla H, and Teunen D. (eds) (1995). Data Analysis and Optimisation in Quality Control and Radiation Protection of the Patient in Diagnostic Radiology and Nuclear Medicine. Proceedings of the Workshop jointly organised by the CEC, the Unita Sanitaria Locale No.7, Udine (I) and the World Health Organisation, held in Grado (I) 29 September - 1 October, 1993. **Report EUR 15257 EN Radiation Protection Dosimetry**. *57* Nos 1-4 .

EUROPEAN FEDERATION OF ORGANISATIONS FOR MEDICAL PHYSICS (EFOMP)

K.A. JESSEN[(1)], President of EFOMP

Medical physicists are primarily and professionally engaged in the application of physics to medicine and biology in clinical, research, and educational institutions. The practice of medical physics varies under this general description from country to country throughout Europe and even between institutions within the countries variations can be observed. Different education requirements and legal status are the main cause of these variations. Within individual countries national organisations work on improvements and provide information and guidance on the training, responsibilities, organizational relationships and roles of persons in the field of medical physics.

The suggestion that the medical physics profession in Europe would benefit from bringing national societies together was first discussed in 1978 and the European Federation of Organisations for Medical Physics was founded in London in May 1980 with 14 founder members. In 1995 EFOMP has 25 member societies, representing some 5100 individual scientists.

It was a general feeling in the late seventies, that there was an urgent need to raise the professional status and increase the political awareness of medical physics in Europe and that the new body should aim to establish itself as "The voice of Medical Physics in Europe". Since that time there has ever been a pressing need to harmonise the differences between countries in Europe, especially within the European Union, where freedom of movement and employment has been in effect since 1992. It is not appropriate that each national organisation has to develope its own chain of experiences, but it is obvious, that we in the European region should take advantage of the results obtained by the most developed organisations in order to accelerate a harmonization of the differences and in this way to promote the best practice of medical physics in the whole region.

The aims of EFOMP are described in the constitution: to foster and coordinate the activities of member organisations; collaborate where appropriate with national and international organisations; to encourage exchanges between the member organisations and disseminate professional and scientific information through publications and meetings; to propose guidelines for education, training and accrediation programmes and making recommendations on the appropriate general responsibilities, organisational relationship and roles of workers in the field of medical physics.

The administration of EFOMP is held by the Council and by the Officers. The Council is formed by two delegates form each member organisation and meets once a year. The Officers are nominated for a 3-year term by the EFOMP Council.

The reason for two delegates is related to the main work of EFOMP being conducted in the two main Committees - the Scientific Committee and the Education, Training and Professional (ETP) Committee. In the Scientific Committee the main tasks are the organisation of scientific meetings and the sponsoring of scientific journals. The tasks of the Education, Training and Professional Committee are described by Dr. Inger-Lena Lamm in the present book.

The Publication and Electronic Communications Committee is mainly concerned with the publication of the newsletter "European Medical Physics News", and exploring the possibilities of electronic mail for EFOMP's purposes.

From its start the Federation has aimed at a close working relationship with the European Union and its administration in Brussels and Luxembourg. Over the past ten years the Federation has responded to those Directives issued by the EU which have influence on the practice of medical physics and EFOMP is now accepted by the EU as the body which speaks for medical physics in Europe.

EFOMP works in collaboration with the **I**nternational **O**rganisation of **M**edical **P**hysics (IOMP), which represents the medical physics associations from all over the world. There are discussions within IOMP to organise itself on a regional basis: in this event EFOMP has been asked to act as the European regional liaison group.

The Federation represents a unique information network with linkage to medical physics organisations throughout Europe and collaboration with bodies such as ESTRO, EAR, WHO and IAEA is an important way of promoting the profession of medical physics.

An increased involvement of colleagues from Central and Eastern Europe would be desirable - with the political barriers removed we can now hope for this to evolve in the not too distant future. The European Conference on Post-Graduate Education in Medical Radiation Physics is an important step in that direction to establish the required levels of education and training and to help achieve parity of professional standards of medical physics in Eastern and

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Western Europe.

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POST-GRADUATE EDUCATION IN MEDICAL RADIATION PHYSICS - THE EFOMP VIEW

I.-L. LAMM[(1)]

INTRODUCTION

The European Federation of Organisations for Medical Physics, EFOMP, was inaugurated in May 1980 as an umbrella organisation for National Medical Physics Organisations. National activities would be strengthened and made more effective by bringing about and maintaining a systematic exchange of professional and scientific information, by the formulation of common policies on the responsibilities and roles of the medical physicist, on training programmes etc. From 1980 to 1995 the number of national member organisations has grown form 14 to 26.

The aims and purposes of EFOMP are defined in Article 4 of the constitution, and among them are:

- proposing guidelines for education, training and accreditation programmes;
- encouraging scholarships and the exchange of Medical Physics between countries;
- making recommendations on the appropriate general responsibilities, organisational relationships and roles of workers in the field of Medical Physics.

The EFOMP activities are directed by the Council and the practical management is referred to one of the two working committees, the Scientific Committee and the Education Training and Professional (ETP) Committee, when applicable.

EFOMP SURVEYS ON EDUCATION AND TRAINING

One of the first EFOMP activities was to make a survey of the medical physics education and training in the member countries. The survey showed that in nearly half of the countries there was no recognised training programme. The result was published in 1984 in the EFOMP policy statement "Medical Physics Education and Training: The present European Level and Recommendations for its future Development". In this policy statement EFOMP recommended that properly structured education and training should be introduced with:

- well defined entry criteria - usually a first degree with physics as a major subject;

- postgraduate education in medical physics lectures, seminars, practical and tutorial work;
- on-the-job training - under the supervision of a medical physicist at a senior level;
- examination - and certification as a qualified medical physicist.

Since then there has been steady progress in the introduction of training programmes. In the 1991 survey, 17 countries reported having training programmes even if all programmes were not yet fully satisfactory.

In 1993 EFOMP made a survey on the number of trained medical radiation physicists working in radiation therapy, diagnostic radiology and nuclear medicine. Answers were received from 18 countries, giving a broad overview of the European situation.

Trained medical radiation physicists per 10^{-6} population in Europe (1993)

	Radiation therapy	Diagnostic radiology	Nuclear medicine
Maximum	6.5	4.3	4.9
Minimum	1.0	0.1	0.3
Median	3.0	0.8	1.6
Upper quartile	4.4	1.9	3.0

The survey covered both trained medical radiation physicists and trained radiation physicists with at least five years of relevant experience since completion of training. The number of physicists with five extra years of experience were markedly lower than the total number of trained physicists, probably reflecting the fact that medical radiation physics is a relatively young and growing profession. In radiotherapy, for example only around two thirds of the trained physicists had more than five extra years of relevant experience.

Allowing for fairly large uncertainties in the figures reported, certain useful conclusions can still be drawn. There is a large variation in numbers between different countries, especially in diagnostic radiology. Some countries have almost no physics support in nuclear medicine and diagnostic radiology. Half of the countries have less than three radiotherapy physicists per million of the population.

It is obviously a difficult task to specify minimum numbers of trained physicists required per million inhabitants, as the numbers also have to depend to some extent on the amount of equipment available and the complexity of examinations and treatments. If standards in health care in Europe are to be harmonised by levelling up rather than down, it is reasonable to consider the staffing levels in those countries that are relatively well equipped. A useful guide could be the upper quartile figures presented above. EFOMP, as well as other organisations, has published recommendations on minimum staffing levels (Criteria for the Number of Physicists in a Medical Physics Department: EFOMP policy statement 1991). A review of future requirements for cancer services in London, made by Professor S Dische, suggests 4.5 trained physicists per million, while the EFOMP recommendations indicate about six physicists per million for the corresponding routine workload, excluding development and teaching. Very few countries in the survey lie in this range, 4.5 - 6 physicists per million. The EFOMP recommendations would suggest about two physicists per million for a fully equipped diagnostic radiology department and about four physicists for nuclear medicine; again, very few countries have staffing levels that meet the EFOMP minimum recommendations.

COOPERATION WITH THE CEC

Directives of the commission of the European Communities, CEC, relating to basic safety standards and radiation protection of the patient have provided a big stimulus to the discussion of training requirements in medical physics especially medical radiation physics. As a legal instrument "*A Directive shall be binding, as to the result to be achieved, upon each Member State to which it is addressed but shall leave to the national authorities the choice of form and methods*". Even if the CEC directives are binding only for Member States, they do affect every European country. It is therefore necessary for all National Organisations in EFOMP to be familiar with the directives related to the medical physics profession.

The directives related to the exposure of individuals are the Directives 76/579/Euratom, amended as 80/836/Euratom, and further amended as 84/467 Euratom, laying down the basic safety standards for the health protection of the general public and workers against the dangers of ionising radiation. The 1980 directive is the most informative, and it has been further amended by Directive 90/641/Euratom, (equivalent protection for outside workers as for permanent staff) and Directive 84/466 Euratom, (specifically related to health care, medical exposures).

The Directive 84/466, The Patient Protection Directive, lays down the basic measures for the radiation protection of persons undergoing medical examination or treatment. This Directive contains the following statements:

Article 2, Paragraph 1:
Without prejudice to Directives 75/362/EEC and 75/363/EEC as amended by Directive 82/76/EEC, and Directives 78/687/EEC, Member States shall take all appropriate measures to ensure that any ionising radiation used in medical procedures is effected under the responsibility of doctors or dental practitioners or other practitioners who are entitled to perform such medical procedures in accordance with the national legislation and who during their training have acquired competence in radiation protection and received adequate training appropriate to the techniques used in medical and dental diagnostic radiology, in radiotherapy or in nuclear medicine.

Article 5:
A Qualified Expert in radiophysics shall be available to sophisticated departments of radiotherapy and nuclear medicine.

EFOMP was invited by CEC officers to assist in the interpretation as well as the implementation of Article 5. In 1988, the policy statement "Radiation Protection of the Patient in Europe: The Training of the Medical Physicist as a Qualified Expert in Radiophysics" was published. In this policy statement EFOMP identified the Qualified Expert in Radiophysics, the QE(r), described the role of the QE(r) and recommended an education and training programme for the QE(r).

EFOMP proposed the following description of the QE(r), which has also been accepted by the representatives of the national authorities of the CEC Member States:

> "The *Qualified expert* should normally be a suitably experienced physical scientist who would be responsible for the safe application of radiological techniques in respect of the protection of the patient. This person would normally work in a hospital, or in a recognised analogous institution and would have knowledge and training in radiation physics appropriate to services where the quality of the diagnostic image or the precision of the treatment is important and the doses delivered to patients undergoing these medical examinations or treatments must be strictly controlled".

The role of the QE(r) as accepted by the national representatives reads as follows:

- to carry out physical measurements related to evaluation of the dose delivered to the patient and to take responsibility for dosimetry;
- to improve any conditions that leads to a reduction in patient dose;

- to lay down tests in the field of quality assurance of the equipment;
- to ensure the surveillance of the installations with regards to radiological protection;
- to choose equipment required to perform radiation protection measurements both in diagnosis and therapy and to give advice on medical equipment;
- to take part in the training of medical practitioners and other staff in relevant aspects of radiation protection;
- to provide skills and responsibilities that complement those of medical practitioners as mentioned in Article 2 paragraph 1 EEC Directive 84/466 Euratom.

In the education and training programme recommended for the QE(r), three main elements were identified:

- a basic course covering fundamental principles
- a special course in the three main fields of application
- practical experience

Several countries and National Medical Physics Organisations do not have the means to organise these special courses themselves. In order to make the special courses available to all physicists, the CEC cooperates with EFOMP by financially supporting the Summer Schools, which EFOMP has introduced in the three specialists areas for the QE(r). The EFOMP Summer Schools are becoming more and more popular, and three Schools have already been organised.

Advanced Summer Schools organised by EFOMP for the QE(r)

Date	**July 1991**	**June 1992**	**June 1994**
Subject	**Nuclear Medicine**	**Radiotherapy**	**Diagnostic Radiology**
Location	**Dublin, Ireland**	**Sevile, Spain**	**Nancy, France**
No of Lectures	**9**	**15**	**17**
No. of participants*	**42**	**45**	**60**
Countries represented	**17**	**12**	**15**

*including lecturers

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EFOMP and National Organisations have emphasized strongly the importance of including diagnostic radiology in Article 5:

i) the use of X-rays in diagnosis is the source of the highest man-made radiation dose to the population:

ii) a number of complex high dose procedures are now in use:

iii) surveys have shown a wide range of doses for the same official version of Article 5, and "les installations lourdes de radiotherapie et de medicine nucleaire" in the French, are not exact translations and are not very helpful. EFOMP has suggested ways of describing the QE(r) and his roles and responsibilities, avoiding this problem. The cooperation with the CEC also continues in connection with the now ongoing revision of the Patient protection Directive.

COMPETENCY BASED TRAINING AND CAREER DEVELOPMENT

The details of education and training programmes differ a great deal from country to country, and it is not the intention of EFOMP to try to standardise them. Instead, EFOMP takes the view that it is important to focus on the tasks the trained medical physicists must be competent to do. A structure with five competency levels has been assigned to cover the full career development for a medical physicist.

Competency Level	Education, Training, Experience
1 Relevant first degree or equivalent	Adequate knowledge on a relevant scientific discipline to a level normally expected of a university diploma in physics or equivalent academic degree.
2 Completion of specialist education	Adequate span of theoretical knowledge to current state of the art, able to apply this knowledge with reasonable skill, under supervision; able to explain problems to other specialists and discuss response, with appropriate vocabulary.
3 Completion of practical training	Adequate span of practical knowledge plus a demonstrated capacity for interpreting the state of the art, to non-specialist clients, professionals in related disciplines, students, enforcing authorities or administrators; able to perform given or routine professional tasks without supervision; able to estimate project budget and manpower costs and delivery schedules.

4 Advanced practical experience	Demonstrated practical capability for applying theoretical knowledge and experience to give timely, economic and appropriate solutions to particular problems and hypothetical scenarios; fluent communicator, competent presenter of ideas, effective teacher and/or manager
5 Mature overview and greater responsibility	Capability for managing a range of routine services, record of significant contribution to the state of the art by initiating/developing research or development; ability to promote new thinking and adoption of novel perspectives, ability to manage change and resolve conflict.

Recognition as a qualified medical physicist, a trained medical physicists, should follow completion of level 3. Competency level 5 would be appropriate for the head of a Medical Physics Department or a large section.

The tasks and duties of the physicist in the three main specialist areas in radiation physics have been analysed, expressed in competency format and assigned a competency level. Examples of competency levels assigned to tasks in radiotherapy, for dosimetry applications and advice on choice of treatment machines, are:

Level	**Dosimetry**
2	Knowledge of calibration chain from National Physics Laboratory to field instruments;
2	Knowledge of basic principles of radiation detectors;
3	Use of ionisation chambers and dosimetry systems for measuring treatment machine output, beam symmetry, beam data for treatment planning systems;
3	Measurement of does in vivo, knowledge of available techniques and necessary calibration and quality assurance procedures for their use;
4	Writing and organising of protocols for dosimetry measurements;
4-5	Assessment of various National and International protocols and consideration of their applicability to local circumstances;

Advice on choice of treatment machines:

2-3	Carrying out commissioning measurements according to a written protocol under the direction of a more senior staff member;

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3-4	Writing and organising commissioning program for radiotherapy treatment machine, to provide clinical data and to ascertain that the machine meets its specification;
4-5	Assessing likely reliability, suitability for task, compliance with current regulations, servicing arrangements;
4-5	Assessing resource requirements for commissioning new radiotherapy treatment machines.

As the requirements of a QE(r) include (i) demonstrable problem solving skills, including the ability to define a problem and formulate strategies for solving it, (ii) the ability to interpret novel or non-standard data, (iii) the ability to make value judgements in unfamiliar situations, (iv) the ability to communicate scientific advice clearly and accurately to others, (v) the ability to recognise fault situations, e.g. inappropriate images, and take suitable corrective action and (vi) appreciation of the limitations of one's knowledge, EFOMP would recommend completion of level 4 as the appropriate level for the QE(r). But, considering the result of the survey on the number of trained medical physicists, this may not be realistic at present.

NATIONAL REGISTRATION SCHEMES

As already stated, one of the aims of EFOMP is to propose guidelines for accreditation programmes. Already in the 1984 policy document, the idea of a European certificate was put forward. In the 1988 policy document the last paragraph reads "Appropriate arrangements should be made for assessment and certification of Qualified Experts either by the competent authorities or by the national professional organisation for medical physics. The certificate awarded on successful completion of the designated training should be formally recognised by the competent national authority as indicating a Qualified Expert in radiophysics".

The current EFOMP view is that EFOMP should not be over-prescriptive in this matter but should instead guide National Organisations. Therefore, EFOMP has recently adopted guidelines for National Registration Schemes for Medical Physicists. These guidelines include the following criteria that EFOMP will look at before accepting a national Registration Scheme.

- A clear statement of the aims of the scheme.
- A properly constituted Registration Council.
- A clear statement of criteria of scientific knowledge and practical competencies for inclusion on the Register.
- Evidence that there is a training programme consistent with the EFOMP

policy statements on training.

- A mechanism for identifying specialist areas of registrants.
- A regular renewal mechanism with a requirement for evidence of continuing activity in the area.
- Agreed rules of professional conduct.
- Interpretation of Professional Misconduct and procedures for disciplinary action.

Formal recognition by EFOMP of a National Registration Scheme will by extrapolation also recognise the qualifications and competence of anyone on the register. This recognition will provide a guarantee to patients that uniformly high standards of medical physics are being attained as well as facilitate free movement of medical physicists throughout Europe. For National Organisations, the register will help in discussions on training requirements and staffing levels. It will also strengthen the position of EFOMP in the discussions with the European Union on the role and responsibilities of the medical physicist, and might in the long term perspective lead to a European certificate.

CONCLUSIONS

- Training arrangements in Europe have improved steadily since the EFOMP policy statement of 1984.
- The number of trained medical radiation physicists is still unacceptably low in many countries.
- An effective working relationship on education and training has been established with the CEC.
- Statutory or indicative Registration Schemes guided and formally recognised by EFOMP will strengthen the position of EFOMP in the future discussions on the role of medical physics.

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PRACTICAL EXPERIENCES IN THE ORGANISATION OF THE IAEA TRAINING ACTIVITIES RELATED TO RADIATION PROTECTION AND QUALITY ASSURANCE IN MEDICINE

A. BENINI[(1)]

INTRODUCTION

The International Atomic Energy Agency (IAEA) is an organisation within the United Nations family, with the objective to expand the contribution of atomic energy to peace, health and prosperity throughout the world.

The application of ionising radiation in medicine for both diagnostic and therapeutic purposes is a significant part of the IAEA programme. In fact, in a number of developing Member states, medicine is one of the principle applications of ionising radiations. A brief introduction to the IAEA's Radiation Protection-Radiation Safety programmes is necessary in order to explain the Agency's approach to radiation protection in medicine.

The increased efforts by the Agency on radiation safety systems are a direct, immediate response to requests from more than 60 developing Member States for assistance in this area. Many of the Member States still rely entirely on the Agency's support and co-operation in establishing a solid infrastructure for carrying out programmed activities in radiation safety that are required at a national level. There are rapidly growing needs for applications of ionising radiation and radioactive sources in medicine, in most developing Member States, but often these needs can neither be properly absorbed nor co-ordinated, due to inadequate radiation safety infrastructures at national and hospital levels. In practical terms, this is reflected by insufficient financial and manpower resources, deficiencies in/or lack of legislation on radiation protection, as well as poor or non-existent programmes of radiation protection and quality assurance. In this perspective very little attention, if any, is paid to the practical implementation of quality control and maintenance and it is known that much of the equipment provided by the IAEA to developing countries, does not function properly or is out of order within a short period of time.

Training activities are an essential part of the IAEA programmes and are organised within different frameworks.

RADIATION PROTECTION ADVISORY TEAM

The IAEA first offered the service of Radiation Protection Advisory Team

(RAPAT) in 1984, and to date about 60 missions have been completed. Each RAPAT consists of three or four experts on different aspects of radiation protection and associated areas, who are recruited both from the IAEA staff and externally (including WHO). The duration of a mission is normally one week. The purpose of RAPAT is to make a general assessment of the radiation protection infrastructure in the Member State visited. The RAPATs make recommendations to the ministries and to the authorities in the country and to the Agency in order to define immediate needs and long term strategies for technical assistance and co-operation. The RAPAT recommendations should be considered as an umbrella for radiation protection aspect. Inter alia, medical application of ionising radiations is given particularly careful consideration in all RAPAT missions.

A number of group training activities, both at regional and national levels, was organised within the RAPAT follow-up programme.

TECHNICAL CO-OPERATION PROJECTS

The technical assistance and co-operation programme is a major instrument of the IAEA. Under this programme the Agency has, among other things, provided developing countries with X-ray machines, gamma cameras, cobalt units, accelerators and radioactive sources for medical purposes, the benefits of which are well known, but the application presents a radiation hazard if the equipment is not properly used and maintained. Consequently, programmes on radiation protection, quality control and maintenance are introduced as an integral part of the technical co-operation programme.

The technical co-operation activities are divided into two regional projects as follows:
ARCAL for Latin America, RCA for Asia and the Pacific, RER for Europe and the Middle East and RAF for Africa. In conjunction with these projects various forms of support are feasible: training courses, expert missions, fellowships and purchasing of equipment.
Training activities at interregional, regional and national levels are organised within TC. Regional activities are planned accordingly to the above mentioned geographical distribution. In Africa the same activity is usually planned for French and English speaking countries separately. Regional trainings are therefore planned well in advance. National training activities usually more practically orientated (workshops) are often organised under the umbrella of national TC projects, using the expert time available to invite experts to give lectures and eventually stay over to advise on the situation in the country.

The general approach of this kind of training is of the kind "train the trainers", as the participants are supposed to be in the position to organise other local training.
A few persons per country will participate in a regional training. The major topics are radiation protection quality assurance and dosimetry techniques in the various medical fields.

National workshops are designed to meet the requirements of the country and are usually very flexible in the structure. Special workshops are tailored for Health Physicists, Medical Physicists and Radiographers.

CO-ORDINATED RESEARCH PROGRAMMES

Co-ordinated research programmes (CRP) can be launched by the IAEA, and one of the goals of the IAEA's CRPs is to network Institutes. Valuable opportunities are offered to researchers in developing countries to meet and exchange experiences. They are particularly effective when operating parallel with other forms of technical aid provided by the IAEA, or other international organisations. A typical contract runs for three to five years. The results of a CRP are often published by the IAEA as a TECDOC and distributed on request, free of charge.

CONCLUSIONS

Within the IAEA, the activities regarding the medical applications of ionising radiations are carried out by various departments: (1) Technical Co-operation, (2) Nuclear Energy, (3) Research & Isotopes. Each department has its own approach but actions are well integrated, co-operation and exchange of information are satisfactory.

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THE INTERNATIONAL FEDERATION FOR MEDICAL & BIOLOGICAL ENGINEERING

V.C. ROBERTS(1)

INTRODUCTION

In 1959 a group of physicists, medical engineers and physicians met in Paris to create an organisation entitled International Federation for Medical Electronics and Biological Engineering. At the time there were few national societies and workers in the discipline joined as Associates of the Federation. Later, as national societies were formed, these societies became affiliates of the Federation. In the mid 60's the name was shortened to its present form.

The Federation now has a total membership of some 40 Affiliated National Societies. It has also recently changed its constitution to allow it to admit to membership a small number of Trans-national Societies, whose activities and membership are drawn from more than one country.

The affairs of the Fereration are administered under an Administrative Council whose eight members are elected at each tri-ennial General Assembly nominations from the Affiliated National Societies. In addition to the elected Councillors there are a President, Vice-President (President elect), Treasurer and Secretary General. The Federation's Secretariat is currently based in the Netherlands[1].

PURPOSE

The purpose of the IFMBE is to foster the development of medical and biological engineering throughout the world. The IFMBE achieves this through a number of means. Most conspicuously it is responsible for organising an International World Congress, held in collaboration with the International Organisation for Medical Physics (IOMP), every three years. The IFMBE, together with the IOMP are affiliated under the umbrella of the International Union for Physical and Engineering Sciences in Medicine (IUPESM) which itself is in the process of affiliating to the International Council of Scientific Unions (ICSU), the most senior scientific body in the world. In addition to its World Congresses, the Federation sponsors a number of regional conferences, in Europe, Asia and the Americas. Scientific papers from the Federation's conferences are often published in the Federation's international journal, *Medical & Biological Engineering & Computing*, among others.

Medical Radiation Physics

In addition to its conference and publication activities, the IFMBE has a number of Divisions and Working Groups, established from time to time to address specific tasks. The Divisions, though under the administrative umbrella of the Federation's Administrative Council, have considerable freedom of action. The IFMBE has a *Clinical Engineering Division* whose activities are concentrated on the development of clinical engineering (encompassing medical equipment management) throughout the world. An International Register of those working in this field has recently been published. A *Division on Technology Assessment in Health Care* has recently been established.

In addition to its Divisions, the IFMBE has Working Groups on Cellular Engineering, Asian-Pacific Activities and European Activities. The former has been particularly active and has recently been associated with a number of very successful conferences devoted to a rapidly expanding field. The Working Group on European Activities has recently been re-constituted and will be addressing extension of its activities to Eastern Europe. At present it is addressing the problem of bringing together a group of experts and institutions in the Western European countries who can work with the counterparts in Eastern Europe. It is planning contributions at conferences throughout Europe over the next few years.

The IFMBE has always been pleased to support ventures which will encourage and enhance and the international community of medical engineering and medical physics. A recent development has been the move towards the establishment of an Academy of Medical & Biological Engineering. This move has been supported by the General Assembly and endorsed by the Administrative Council. It seems likely that the Academy will be established before the next World Congress to be held in Nice in 1997. The principal of the Academy is to conduct programmes which will serve to encourage young people entering the field and their development in the early stages of their careers.

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Austria

EDUCATION AND TRAINING OF MEDICAL PHYSICISTS IN AUSTRIA

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INTRODUCTION

The Austrian Society of Medical Physics (OEGMP) was founded in 1980. At present, it comprises about 135 members. About 50% of them are employed by hospitals. The main scope of activities is within radiotherapy, nuclear medicine and diagnostic radiology. There are a few more who work in the field of ultrasound and medical laser applications. The other half of the members consists mainly of employees of government agencies, but there is also a substantial proportion working in industry.

Education and training has been of primary concern to the OEGMP. The basic document which served as a guideline for the efforts to introduce post-graduate training was the EFOMP Policy Statement on Education and Training of Medical Physics in Europe. Another important guideline used was the DGMP document specifying in detail the requirements for post-graduate training of medical physicists in Germany. Both documents were the main input for producing an Austrian document laying down the situation of medical physics in Austria and the requirements for a post-graduate education, which was published in 1988. Based on this document, the University of Vienna initiated a post-graduate course for medical physics of three years duration. The course was officially recognised by the ministry of Science and Research in 1989 which also awarded the official title of "Akademisch geprufte(r) Medizinphysiker(in)" to the students of the course having successfully completed all required examinations. Official recognition by the Ministry at the same time signified official recognition of the specialty of medical physics as a profession.

UNIVERSITY COURSE FOR POST-GRADUATE TRAINING OF MEDICAL PHYSICISTS

Entrance requirements

The students accepted must hold at least an M.Sc. in physics or biomedical engineering. Also graduates in the specialty of electrical engineering are accepted, but they have to provide proof of having satisfactory knowledge on atomic and nuclear physics.

Structure of the course

The duration of the course is six semesters, i.e. three years. Lectures and laboratory courses are organised to take place seven times per semester: they are held on Friday and Saturday tenable the participation of medical physicists who are already employed. About 60% of the course accounts for lecture time and 40% for laboratory courses. Each semester comprises as a minimum about 90 hours of both teaching and laboratory work, thus totalling 540 hours of lecture and guided laboratory work throughout the course.

The topics follow the usual layout for medical physics. There are two groups of compulsory lectures and laboratory courses, the first one covering basics of medicine and medical physics, and the second one dealing with topics of medical radiation physics. The third group includes other lectures in medical physics from which the participant may make a selection of his or her own according to interest and which may vary depending on availability of lectures. A tabular summary of the topics is given in the appendix.

The student has to pass an exam covering each of the lectures. Participation in the laboratory courses is also evaluated.

For a successful completion of the course, the student has to give either a written survey on a particular topic in medical physics supervised by one of the lecturers or to submit a published scientific paper in which he/she is the first author.

The student has to take a final examination before a board of examiners consisting of three members recruited amongst the lecturers.

The number of participants per course is limited to 25. The first course started in 1990 with nine participants the second and third courses started off with 25 participants. The drop-out rate is surprisingly low, with about 90% of the participants finishing the course.

The course organised by the Vienna University meets the requirements with regard to formal education as laid down by EFOMP in its recommendations on post-graduate training. However, such a university course cannot offer on-the-job training at the required extent. Although believed to be much more efficient than on-the-job training, in addition to the laboratory courses further supplementary practical experience is required.

Medical Radiation Physics
THE "FACHANERKENNUNG"

In order to remedy this situation and to make post-graduate training of medical physicists compatible to that of other European Countries, the Austrian Society has designed a "Fachanerkennung" similar to those that have been introduced already in Germany and in Switzerland.

The "Fachanerkennung" finally has to be accepted by the members of the Society. A draft is, however, already available. In general, the structure follows the recommendations laid down by EFOMP as regards both the extent and duration of the training. Special consideration, however, is given to students who have successfully completed the post-graduate training course at the Vienna university. These clearly meet all the requirements of formal education and do meet part of the requirements for practical training. Depending on their individual curriculum, they may obtain the "Fachanerkennung" already after one and a half years' time of on-the-job training instead of the usual three years as is required from medical physicists who pass through the normal curriculum of post-graduate training.

CONCLUSION

The Austrian facilities for post-graduate training offer the physicists ample opportunity to qualify as a medical physicists according to the standards set up by EFOMP. The Austrian Society is in contact with other German-speaking societies of medical physics to negotiate mutual recognition of the "Fachanerkennung". It is hoped that mutual recognition can be achieved with other European Countries to help to establish medical physics as a recognised profession throughout Europe.

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Appendix

Curriculum of the post-graduate training course in medical physics at the University of Vienna

Hours /semester
(V - Lecture, P - Laboratory course)

a.	**Basic Sciences:**			
	1.	Anatomy	30	V
	2.	Physiology	30	V
	3.	Biophysics	15	V
	4.	Biomathematics and informatics	15	V + 30 P
	5.	Biomedical engineering	15	V
	6.	Hospital Management	15	V
	7.	Methods of physical measurements in medicine	15	V + 15 P
b.	**Compulsory Topics**			
	1.	Radiation therapy	60	V + 45 P
	2.	Nuclear Medicine	30	V + 30 P
	3	Diagnostic radiology	30	V + 15 P
c.	**Additional Topics:**			
	1.	Medical optics	15	V + 30 P
	2.	Medical applications of lasers	30	V + 30 P
	3.	Medical acoustics	15	V
	4.	Medical ultrasound	30	V + 15 P
	5.	Physical medicine	15	V
	6.	Digital image processing	30	V + 30 P
	7.	Magnetic resonance in medicine	30	V + 15 P

Belarus

MEDICAL RADIATION PHYSICS IN BELARUS

I. G. TARUTIN[(1)] and A. G. STRAKH[(1)]

STATUS

At present time, the approximate number of radiation physicists and engineers involved in radiation medicine in Belarus is 32. The population of Belarus is 10 million. This gives only 1.2 physicists per million inhabitants - one of the lowest levels in Europe.

The radiation physicists and clinical engineers involved in medical application are mainly concentrated at the Research and Development Institute of Oncology and Medical Radiology in Minsk (22): radiotherapy - 6 physicists and 11 engineers: nuclear medicine 2 engineers: radiation protection - 1 physicist and 2 engineers. We have 12 radiotherapy regional hospitals. There are about 5 physicists and 5 engineers employed mainly in radiation therapy departments.

At present in Belarus 26 $Cobalt^{60}$ units are being used , 14 units are available for brachytherapy and there are 7 treatment planning systems.

EDUCATION

The Physics Faculty of Belorusian State University is the main source of physicist staff in Belarus. The 5 year course consists of two years of basic courses in mathematics and physics. In the following three years the radiation physics syllabus covers atomic, nuclear and quantum physics, radiation sources, interaction between radiation and substance, detectors and methods of dosimetry, radiobiology, radiation protection, diagnostic X-ray physics, imaging and non-ionizing radiation. Arriving at health service centres the graduates have no previous knowledge or experience in any medical topics.

Post-graduate training is done on an individual basis. Usually a candidate for medical physics undergoes training in clinical practise under the supervision of more experienced colleagues. There is no formal graduate training in medical physics. Some physicists have been trained in other institutes and have attended courses and meetings before 1991 (In the former USSR). Post-graduate training courses in medical physics had been organised periodically at the Medicine Institute High Specialisation in Moscow. This education has included a number of 3 months special courses: brachytherapy, clinical dosimetry, therapy planning. These courses had been made available to only 4 physicists before 1991.

The engineers' duties include installing, checking and maintaining the equipment, special repairs and supplies, technical assistance for setting up of X-ray machines usually without the necessary training. Physicists deal mainly with routine duties in hospitals. Only a few of them are involved in research and educational activities.

A few medical radiation physicists (3) from Belarus obtained their "Doctor of science" degree (Ph.D) in different specialities (not in medical physics). Up to 1991 this had been provided individually in different ways. The post-graduate education system (of the former USSR) at some Universities and Research institutes had included Ph.D theses in medical physics. It had been possible to prepare an individual research project according to the needs of the medical department where they had been employed.

FUTURE NEEDS

We would like to develop an advanced medical physics programme of education and research in our republic. However, since 1991 in Belarus there has been no organised training system due to the lack of such type of official education system and also because of financial difficulties. Our participation in international scientific events is minimal and modern literature and equipment for education in Medical Physics is not available. Two physicists attended the International Summer School "Physics in Radiotherapy" in 1993, Warsaw (supported by the Developing Countries Committee of the International Union for Physics & Engineering Science in Medicine (IUPESM) and one physicist attended the regional training course on radiobiology treatment planning which was held in Turkey in 1993 (supported by IDEA). We are grateful for this support as due to the low monthly salaries (20-30 US) we cannot otherwise attend the international medical physics programmes and meetings. A good solution to our immediate problems could be for our graduates to undergo training on a regional basis at the Ph.D level in different Western Hospitals which are well equipped for research activities in medical physics.

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Belgium

MEDICAL RADIATION PHYSICS AND POST-GRADUATE EDUCATION IN BELGIUM

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INTRODUCTION

Belgium has three regions, (Wallonia, Flanders, Brussels) and two Communities (Dutch speaking and French speaking, the German speaking community is a minority) in a federal state organised country.
Facts that are important for Medical Physics, are:

- Education (including at University level) is now dependent on the different communities:
- Health Services, Social Security and Radiation Protection is controlled by the Federal Government.

This politically complicated situation makes co-ordination between the practice of medical physics and the education and recognition (status) very difficult.

THE BELGIAN HOSPITAL PHYSICISTS' ASSOCIATION

The Belgian Hospital Physicists' Association (SBPH-BVZF: Société Belge des Physiciens des Hôpitaux-Belgische Vereniging Ziekenhuis Fysici) is still a unitarian association and covers the whole of Belgium (communities and regions). The Society has about 75 members in 1994. It was founded in 1978 and represents the medical radiation physicists in all official contracts with governmental or scientific bodies.

HEALTH SYSTEM IN BELGIUM

Public and private hospital and care system co-exist but reimbursements are mainly from social security.
In radiotherapy the physicists are paid by the reimbursement procedure of the social security; treatment planning is reimbursed as well.
In nuclear medicine the physicists are paid by the hospital.
In diagnostic radiology (excluding MRI) no one is paid by the hospital. The very few physicists are paid from research funds.

LEGAL ENVIRONMENT AND DEFINITION OF MEDICAL PHYSICIST

Belgium

The CEC issued the so called patient Directive of September 1984 (1) , this Directive was implemented in the Belgian law system in April 1987 (2) however no clear definition was given of the "Qualified Expert in Radiation Physics". Presently the Belgian Advisory Board on Radiation Protection, the Department of Protection against Ionising Radiation of the Ministry of Health and representatives of the professional bodies (Physicists, Radiologists, Radiotherapists and Nuclear Medicine Physicians) are working out a law defining the education and the recognition of the medical radiation physicists. Three orientations are defined: radiation therapy, nuclear medicine and radiology. This document, if completed, anticipates on a revision of the CEC patient directive, since in the field of diagnostic radiology the responsibility of the qualified expert is orientated towards radiation protection and quality assurance.

The major problem of recognition of the medical physicists is the lobbying of a minority of medical doctors against the legal requirements for a radiation physicist with responsibilities in nuclear medicine and radiology. One of the arguments is that since a law published in October 1993 (3), all specialist MDs using ionising radiation have to obtain a certificate proving that they have followed successfully a minimum of 120 hours of practicals in nuclear physics, methods of radiation measurement, radiochemistry, radioprotection, legislation on radioprotection, radiobiology, radiotoxicology and radiopharmacology.

For radiotherapy explicit rules are set. In April 1991, the Official Journal published requirements for a radiotherapy department: every complete radiotherapy department has to have one physicist, or a person (engineer) competent in physics. For each 750 new patients/year, a second physicist is required and so on. If very specialised techniques are applied (brachytherapy, intra-operative, whole body, etc) extra physicists are needed. Education is, however, not mentioned in the requirements.

PRESENT EDUCATION SCHEME

There are two ways in general education which lead to medical radiation physics:

-First is the education as an "Industrial Engineer". This is a baccalaureate + 4 years education in a technical high school. Two schools have a typical radiation physics orientation. Their education is more practically oriented, with background in electronics or nuclear science.

-The second path goes through university with either engineering degree in physics- (baccalaureate + 5 years), or a university degree in physics (or chemistry)- (baccalaureate +4 years).

Many radiation physicists in the past started working in four Belgian hospitals (after their general education) under the supervision of an experienced senior physicist, without further training. Professional skill and knowledge were obtained on-site, with occasional post-graduate training in summer schools of EFOMP, ESTRO and the CEC.

Presently post-graduate training is organised in four Belgian universities for industrial engineers and several other university degrees (in general, accessible after examination of the applicants curriculum). This education is mostly with duration of one year, and concludes with a small thesis. Very often students spread the courses and exams over two years.

EDUCATION SCHEME UNDER NEGOTIATION

Since 1991 the Belgium Hospital Physicist Association has been cooperating in a working group with the Ministry of Health on the status, responsibilities and education of the medical physicist in nuclear medicine, radiotherapy and radiology. The representatives of the physicists proposed a post-graduate training with a content very similar to the EFOMP recommendations. The negotiations are still going on, but we hope the outcome will be along the following lines:

- Basic education university degree in chemistry or physics, or engineering or equivalent. Industrial engineers can be accepted if the screening commission of the universities give their approval.
- For the post-graduate education itself, with duration of 2 years, three different options can be taken: radiotherapy, nuclear medicine or radiology. A total of 600 hours of courses (anatomy, physiology, dosimetry, radioprotection, radiobiology, quality assurance, techniques of radiology, radiotherapy and nuclear medicine, detection of ionising radiation, legislation,...) and 1 year on site training in one of the disciplines completed by a short thesis.
- A certificate will be obtained after completing this curriculum. this certificate should be requested in the future for recognition as a medical radiation physicist.

This education scheme is part of a proposal from the Ministry of Health. However, education is a responsibility of the universities, hence of the Communities.

This information is of course only tentative. Finalising this in a law can still take some time.

FUTURE NEED FOR HOSPITAL PHYSICISTS IN BELGIUM

There are about 4 "medical physicists" per 10^6 inhabitants in Belgium. This is far from the EFOMP or IPSM recommendations. So there is room for more physicists, but the offer from the hospitals is still rather low at the moment.

In radiotherapy saturation is almost reached, and most of the active physicists are young. If ISO9000 procedures for quality assurance are implemented (as recommended by the CEC and the ESTRO), a slight increase in staffing is possible. Once the legislation is modified, there will be a need for medical physicists in radiology. SPECT and PET applications in Nuclear Medicine will offer some extra positions.

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Bulgaria

MEDICAL RADIATION PHYSICS AND ENGINEERING IN BULGARIA

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STATUS

Applied medical physics in Bulgaria developed since the early 1950's in line with the development of medical radiology in the country. In 1975 a National Secondary Standard Dosimetry Laboratory for ionising radiation was established. Radiation physics & engineering continues to be the most developed part of medical physics in Bulgaria to this day. About 35 physicists are working at the national and regional centres for nuclear medicine and radiotherapy. Nearly 100 specialists, mainly physicists, are working in the radiation protection laboratories associated with various institutions throughout the country, as well as in the respective departments of the Regional Environmental Inspectorates. They work under the methodological guidance of the National Centre of Radiobiology and Radiation Protection at the Ministry of Health.

A small group of physicists and physicians are working successfully in the field of climatology and climatotherapy. Their work is very promising with a view to the good and varied climatic conditions in the country.

Unfortunately medical physics has not yet found its due place in electrodiagnostics and electrotherapy, in medical and dental orthopaedics, in ultrasound diagnosis, in ophthalmology and otorhinolaryngology. For the time being the introduction of lasers for diagnostic and therapeutic purposes also takes place without the participation of physicists.

EDUCATION AND TRAINING IN MEDICAL RADIATION PHYSICS

The main reason for that state of medical physics should be sought in the training of physicists and in the teaching of medical physics to medical students. Applied physics is neglected at the Faculty of Physics at the University of Sofia. This has a negative effect on the training of the students and later complicates immensely the quality selection of teaching staff for the Departments of Physics and Biophysics. On the other hand the administration of the Faculties of Medicine tends to underestimate the fundamental role of medical physics. As a result of this attitude some faculties teach only 75 hours of medical physics (30 hours lectures and 45 hours laboratory practice).

Bulgaria

Postgraduate training courses in medical radiation physics are organized periodically at the High Medical University in Sofia. The training lasts for three years. The training programme is comprised of two parts: a general part for all the trainees and a special part in which the specific individual field of activity is considered. These courses have been made available to several dozens of physicists working predominantly in the sphere of medical radiology, as well as in the Departments of Medical Physics and Biophysics at the Higher Medical Institutes in the country.

In general the education in medical physics in Bulgaria is in a critical situation. In our opinion there are several reasons for that:

1 The education of students in Physics Faculties does not provide reasonably good insight into applied physics and more specifically into medical physics.
2 The prominent physicians tend to underestimate the importance of medical physics. That is most likely to reflect the low level of education in physics which they have received in their medical universities.
3 The isolation of Bulgarian medical physicists from the scientific community in the world - political isolation before and financial isolation now.

A fact of deep concern is the growing average age of the medical physicists' community and the lack of adequate young substitutes. This leads to new vacancies every year and lack of applicants.

X-RAY AND RADIOLOGICAL ENGINEERING

At present about 40 X-ray and clinical engineers (CE) are employed in the Diagnostic Radiology (Roentgenology) field and about 15 CE's - in the nuclear medicine and radiotherapy field. All of them have MSc degrees mainly in electronics. About 10 of them have a PhD degree. Some of the X-ray and clinical engineers have graduated from the course of Medical and Nuclear Electronics at the Technical University of Sofia. This sub-speciality of electronics includes subjects like medical cybernetics, basics of human anatomy and physiology, biomedical engineering, methods and instruments for acquisition, processing and recording of biological signals, medical imaging, X-ray engineering, etc.

A post-graduate course in Medical Engineering (including radiological physics & engineering and medical imaging) was initiated recently in the Technical University of Plovdiv in collaboration with the Medical University of Plovdiv (the module on X-ray engineering from this course consists of 24 h lectures and 12 h practicals). CEs get extra qualifications in the field from specialised firm-courses in connection with purchasing of new high-tech equipment. Most of the CEs have the status of research associates and participate actively in medical engineering investigations. The CEs are usually organised in laboratories within the respective medical department. Active research activities used to be carried out in the Institute of Biomedical Engineering, the National Centre for Radiobiology and Radiation Protection and some of the Laboratories in the Medical Universities.

There are about 10 books on Radiation Physics, X-ray Engineering, Radiation Protection and Medical Engineering from Bulgarian authors published in the last 20 years, as well as numerous other translated books. After 1990 the number of professional books and journals available decreased dramatically.

REPRESENTING BODY

The Scientific Society of Biomedical Physics and Engineering was founded in 1971. The Society has two divisions, which comprise of two main groups of specialists: physicists and engineers working in the field of biomedical physics and engineering.

The activities of the Society focus mainly on the Scientific Conferences on Biomedical Physics and Engineering, which are organised every four years. The six conferences held so far were attended by specialists from all over the country and abroad - USA, France, Germany and UK. The most numerous foreign participants were from the former socialists countries. A WHO Symposium was organised in parallel with the conference in 1988. Due to financial difficulties the editing and distribution of the Journal of the Society ceased some 10 years ago.

The Society has taken the initiative of organising annual colloquia on the role of physics for protection of man and his environment, jointly with the Ministry of Environment.

The activities of the Society also include preliminary approvals of theses for Ph.D; information about the participation of its members in scientific congresses and conferences abroad; reviews of new books in the field of medical physics and engineering; celebrations dedicated to important anniversaries, etc.

Since 1983, the Scientific Society of Biomedical Physics and Engineering is a member of the European Federation of Organisations for Medical Physics (EFOMP) , of the International Organisation of Medical Physics (IOMP) and of

Bulgaria

the International Federation of Medical and Biomedical Engineering (IFMBE). This could be seen as a recognition of the Society's role and prestige.

FUTURE NEEDS

What is the support that could be provided to the Bulgarian medical physics community?

1 Improved contacts with prominent institutes, clinics and laboratories abroad through exchange of information and specialists and collaboration in common scientific research projects. A good example in that regard are the scientific meetings organised in Bulgaria with the help of the Clinical Science Foundation-London. Practically all medical physicists and bioengineers involved in medical radiology participated at those meetings.

2 Regular supply with programs for education and scientific literature. The help of the International Organisation of Medical Physics IOMP and personally of Dr C. Orton in that regard is highly appreciated. A library of IOMP has been established in Sofia. Regretfully we are not able to keep it up-to-date because of financial reasons.

The economic difficulties which Bulgaria has experienced during the last few years had an adverse effect on scientific societies as well. Many of our members, especially young people, went abroad. Our financial resources for organising training courses, regional conferences and working meetings are minimal. Our participation in international scientific events has also decreased sharply. The modern literature and equipment for education in Medical Physics & Engineering is not sufficient. There is a need for collaboration with other Universities and Institutions in the field of education and training.

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Croatia

MEDICAL RADIATION PHYSICS IN CROATIA

M. VRTAR[(1)]

INTRODUCTION

In today's medicine in Croatia the rather wide scope of radiation physics applications, researches and educational activities confirms that the collaboration of technical (i.e. physical and engineering) professions with other health care staff in advanced medicine here has always had a pronounced tradition. However, the number of such collaborations has never been very high. The radiation physicists and clinical engineers involved in medical radiation applications are mainly concentrated at University Clinical Hospital Centres (UHC), General Hospitals (GH), and specialised Clinics for Tumours (SCT), while the physicists engaged in the field of radiation protection and safety work in some research institutes in Zagreb. Currently, nobody is dealing exclusively with diagnostic radiology, but some are engaged periodically in supervision and control of the X-ray equipment. They are mainly the physicists from the Institute for Medical Research and Occupational Health (IMR), where the service for granting operations of the radiation facilities and the personnel dosimetry laboratories is situated. There is also a dosimetry department in the scientific research Institute "Ruder Boskovic" (IRB). At the present time the Croatian state service for standards in radiation dosimetry is in the process of being formed. Previously (in former Yugoslavia) there existed a state regulation based on IEC norms which has been applied continuously in Croatia until the new regulation has been set up. Now, the approximate number of radiation physicists involved in medical treatments in Croatia is about 30: **radiotherapy** (rt) - 11, **nuclear medicine** (nm) - 11, **radiation protection** (rp) - 8. They are working in the following institutions:

Zagreb: Clinic of oncology and radiotherapy UHC "Rebro" (rt - 2), Gynaecological cancer centre (rt - 1),
Clinic of nuclear medicine UHC "Rebro" (nm - 5),
Clinic of nuclear medicine and oncology UCH "S. Milosrdnice" (nm,rt - 3),
Clinic for tumours (rt - 3),
Department of nuclear medicine New Univ. Hospital (nm - 1), Laboratory for dosimetry IMR (rp - 5),
Department for radiation protection IRB (rp - 3).

Rijeka: Clinic of nuclear medicine and oncology UHC (nm, rt - 2)
Medical Faculty (nm, rt - 2)

Split: Department of oncology and radiotherapy GH, (rt - 1)
Osijek: Department of oncology and radiotherapy GH, (rt -1)
Zadar: Department of oncology and radiotherapy GH, (nm - 1)

NATIONAL SOCIETY

As the number of medical radiation physicists in Croatia is relatively low, and there is often overlap between the various engineers of similar professions (such as electro and computer engineers) in clinical hospitals, medical research institutes, specialised laboratories and other skilled areas dealing with health care, we decided to join the Croatian Medical and Biological Engineering Society (CROMBES). The Society was established in January 1992 in Zagreb. In September 1993 the application of CROMBES was accepted and the Society became a member of the International Federation for Medical and Biological Engineering (IFMBE). Now CROMBES has two Divisions: Medical Physics Division (MPD) and Clinical Engineering Division (CED) and about 120 members in all. It has to be pointed out that the members can also be experts from other professions engaged in similar work, for example medical doctors. The MPD was accepted through CROMBES as a member of the European Federation of Organisations for Medical Physics (EFOMP) from October 1993 and our CED became automatically (also through CROMBES) the member of IFMBE-CED. So far our young Society and its MPD has gathered almost all the physicists in medical radiation in Croatia.

MEDICAL PHYSICS DIVISION ACTIVITIES

MPD extends the knowledge of its members and of other professions such as doctors and technicians during their specialization in some associated branches of medicine (radiotherapy, radiology, nuclear medicine), exchanges the experiences with clinical engineers dealing with radiation equipment and instrumentation, organises symposia in connection with Medical Institutions, the Croatian Society for Communications, Computers, Electronic Measurements and Automation (KOREMA) and participates in the meetings of the Society for Irradiation Protection. The principal aim is keeping the members and others with an interest in medical radiation physics in touch with new developments in the field, maintenance of the radiation standards and quality assurance (QA), as a complex process involving all medical and physical steps. Some of the medical radiation physicists have been collaborating in scientific projects, researches and conferences with international organizations (IAEA and ESTRO) or some foreign societies (e.g. Deutsche Gesellschaft fur Medizinische Physik (DGMP) - workshop on physical aspects of Total Body Irradiation - TBI). These were highly successful in including the highest medical standards of radiation applications, for example, in introducing the TBI method in connection with Bone Marrow Transplantation, in establishing the Centre for Prevention of Consequences in Nuclear Accidents, in participating courses concerning the hypothetical accidents in a nuclear power plant, and so on. We also answered the questionnaire on radiotherapy QA requested by the EFOMP Scientific Committee. The physicists working in Clinical and University Hospitals take part in some hours of clinical Oncology & Radiotherapy and Nuclear Medicine lectures at the Faculty for Natural and Mathematical Sciences (FNMS), the Faculty of Medicine and the Faculty of Electrical Engineering (FEE), introducing the students to radiation physics principles and measurements.

EDUCATION OF MEDICAL PHYSICISTS

Study of medical physics at an undergraduate level has not been organized in Croatia until now. However, there is a very famous four year study of physics at the Faculty for natural and mathematical sciences in Zagreb, where the students also have a possibility to hear some themes from medical physics which are involved in subjects of the 4th year of study. At the end of study they get the title "Diplom Engineer in Physics". In post-graduate education study at the same faculty there is a two-year scientific direction named Medical Physics which results in a "master of science" degree (MSc) (after defending the theme). The programme of this study is:

Numerical methods and mathematical modelling
Physics and techniques of ultrasound in medicine
Physical aspects of nuclear medicine
Physics in radiology
Selected aspects of functional anatomy
Selected aspects of radiographic anatomy
Physiology with pathophysiology
Biomedical electronics and instrumentation
Radiation protection

In practice, many of today's medical physicists reached their "doctor of science" degree (Ph.D) after they finished their MSc in nuclear physics and dosimetry. The reason is that Medical Physics is a relatively new direction and the main core of the present radiation physicists population has already been working for several years. Unfortunately, we observed significant difficulties in the internal status and recognition of physicists (and clinical engineers too) in the hospital institutions, clinics and institutes. Namely, although our experts may have MSc and Ph.D scientific levels, can be the members of the highest international associations and are participating in many teams of advanced medical practice enjoying the obligations and activities of the same level of responsibilities as doctors in the medical work, they are treated in today's health regulations law as "non-medical" professions. The reason arises from the non-existence of the form of **organized specialization**, during the study of postgraduate medical physics at FNMS, (which would include on-the-job training, for example in oncology and radiotherapy, radiology or nuclear medicine, as for medical doctors). The final consequence reflects in the inequality in position and (material) status (compared to medical staff).

INTENTIONS FOR IMPROVEMENT OF THE STATUS

Croatia is a country of about 4.5 million of population and a small number of university hospital institutions, so that the experts with wide knowledge of clinical applications are needed. A desire for the improvement of the status of radiation medical physicists and clinical engineers inspired a scientific group (of CROMBES members) with a wide range of expertise from the science disciplines of physics, electrotechnics and computer technic, to propose to the Faculty of Electrical Engineering to organize an expert study (specialization) in **Clinical Engineering.**

This expert study, considered as post-graduate, should cover the interdisciplinary technical branches of medical physics including radiation physics, biomedical electronics and clinical engineering in all its aspects. The participants of the two-year study should be graduates (Dipl. Engineers) in physics or electrotechnics (after 4 years of study) and seconded from the health care institutions (hospitals, clinics, institutes) or should pay from their own resources. The practical residence and in-service training would be in the clinical hospitals in Zagreb. After finishing the final theme, under the supervision of a mentor, the students could reach the title "**Specialist in clinical engineering".** We also expect this title to be recognised by the Ministry of health to facilitate the position of medical physicists in our hospitals. The main subjects of the expert study are outlined below.

POSTGRADUATE STUDY FOR SPECIALISTS IN CLINICAL ENGINEERING

SEMESTER 1

Selected aspects of functional anatomy. Selected aspects of physiology. Medical electronics. Selected aspects of medical physics.

Medical Radiation Physics

SEMESTER 2

Digital signal processing, Digital image processing.
Sensors and transducers.

SEMESTER 3

Physics in radiology and radiotherapy. Physics in nuclear medicine. Bioelectrical signals and systems.

SEMESTER 4

Physics and techniques of ultrasound and non-ionizing irradiations. Electrotherapy and electrostimulation. Systems for extra-corporal support. Clinical engineering and legal regulations.

* practical residence and in-the-job training should be performed for each of the presented subjects in Clinical Hospitals in Zagreb.

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MEDICAL PHYSICS AND ENGINEERING - THE CYPRUS EXPERIENCE

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INTRODUCTION

Cyprus is an island located in the Eastern Mediterranean. Its population reached the 600,000 mark only recently. It gained its independence from British rule in 1960 and in 1974 was invaded by neighbouring Turkey which seized up and occupied 40% of its land. In the meantime it has been trying to catch up with the rest of the world. In this presentation the educational and health care delivery services will be examined and reference will be made to professional groups related to medical engineering and physics.

EDUCATION

The colonial interests would not allow any kind of educational system to develop and the only local education available to Cypriots until 1960 was secondary school, which was non-obligatory and was considered at the time to be a luxury.

Since that time post-secondary-school education has been developing slowly, probably too slow, with the establishment of 4 public institutions in the fields of engineering, hotel and catering, forestry and nursing. The only engineering establishment is the Higher Technical Institute which offers 3-year full time courses in engineering and computers at the Engineering Technician level. In the private sector a number of colleges offer higher education in all disciplines. The University of Cyprus has been established recently, in 1991, and offers education in the fields of art, computing and some science subjects. It is expected that the Applied Sciences and the Engineering Schools will be established soon.

For these reasons all Cypriots who hold a university degree have obtained it abroad, mainly in Greece, the UK and the USA, and have brought into the country a variety of standards.

Medical Physicists and Biomedical Engineers are no exception to this rule. It is also worth noting that when these specifications were created, professionals from related fields were converted after following short courses and seminars abroad.

At present the situation is no different from the above. Our Medical Physicists and Biomedical Engineers receive their education abroad and are forced to follow specialisations which are available to them in various countries.

THE REGIONAL TRAINING CENTRE

In August 1978 a joint project was signed between the World Health Organisation and the Government of Cyprus which set up a Regional Training Centre at the HTI. The aim of this centre is to train different levels of Hospital Technical Personnel. The student eligible to attend are selected from the Eastern Mediterranean Region of the World Health Organisation which stretches from Morocco in the West to Pakistan in the East, the Arabian peninsula and Somalia to the South. Students from other WHO Regions, the commonwealth (CFTC), National Donor Agencies and other countries are also accepted. It is preferable that candidates are employees of their National Health Care Technical Services.

Candidates should be graduates of any of the RTC Specialised Technician Courses or graduates of 6 years Technician Secondary School specialising, preferably in electrical or electronics subjects, with at least three years practical experience in the maintenance and repair of medical equipment. Candidates may be examined in two papers, English Language and Technology.

The centre in recognition of its contribution in this field, was designed as a Commonwealth Centre of Excellence and in 1987 as a WHO Collaborating Centre for Training and Research in Management, Maintenance and Repair of Health Care Equipment. Courses offered by the Centre are:

- Specialised Technician Courses in Medical Electronics (10 month duration)
- Advanced Technician Courses on Electromedical and Clinical Laboratory Equipment, Diagnostic X-Ray and Nuclear Medicine Equipment and Operating Theatre and Dental Equipment (10 month duration)
- Short courses on Logistics of the Cold Chain, Refrigerator Repair Technicians (RRT) and Solar Refrigerator Repair Technician (SRRT). These are of two weeks duration and are organised in collaboration with WHO's Expanded Programme of Immunisation (EPI). In addition the Centre is now in the planning process of providing a 3-month technician course on Diagnostic X-Ray and Nuclear Medicine Equipment. It is hoped that it will be ready for the period September to December 1995.

MEDICAL PHYSICS

There are no facilities or institutions in Cyprus where Medical Physicists can be educated or trained. All the Medical Physicists working in Cyprus have been educated and trained abroad, the majority in the United Kingdom. The Medical Physics Department (MPD) of the Nicosia General Hospital (NGH), the only one in the country, is staffed with one senior physicist, four physicists and six technicians. It is responsible for all matters concerned with ionising radiation in the whole country. Since 1974, after the Turkish invasion of Cyprus, the responsibilities of the MPD are limited to the Government controlled area of the island.

Table 1 Departments using ionising radiation in Cyprus

Departments		**Equipment**		**Number of Physicists**
Type	No	Type	No	
Radiotherapy	2	Co^{60} Superficial X-ray X-ray Brachytherapy	3 1 2 1	1
Nuclear Medicine	3	ã-camera	3	1
Diagnostic Radiology	25	Diagnostic Radiology Diagnostic Flouroscopy Angiography suites CT's Mammography	91 28 2 7 10	2
Dental	58	Dental X-ray	68	

The services provided by the MPD include: Radiation Protection Services, Secondary Standard Dosimetry Laboratory (SSDL), Radiotherapy Physics, Nuclear Medicine, Diagnostic Radiology and Radioactive Waste Management.

The MPD also provides education and training to other related groups:

- Nurses School: The physics part of the syllabus of the three year nurses course of the Nurses School is the responsibility of the MPD.
- Health Inspectors School: The school of Health Inspectors is operated by the Ministry of Health on a demand and supply basis. The school offers a three year course in Health Hygiene. The physics part of its syllabus is the

responsibility of the MPD.

- Regional Training Centre (RTC): The staff of MPD collaborate closely with the staff of the RTC offering theoretical and hands-on training.
- Other Courses and Workshops: With the collaboration of the IAEA and the World Health Organisation (WHO), a number of courses and workshops were organised and took place in Cyprus in the past. Others are expected to be organised in the near future.

BIOMEDICAL ENGINEERING

It would be superfluous to talk about Biomedical Engineering in Cyprus and to attempt to isolate it from other related disciplines such as Clinical and Hospital Engineering. Defining each one of these is difficult enough in any case and attempting to distinguish who is who in Cyprus would be out of the question.

It should be stated, however, that the number of engineers and technicians involved in matters relating directly to patients e.g. implants, not equipment, is limited. Biomedical engineering in its strict definition is confined within the Cyprus Institute of Neurology and Genetics where research is going on in fields of genetics and the processing of electromyographic signals. It is, therefore, quite true to state that the majority of the engineers are involved with health care equipment in the process of acquisition, installation, maintenance, repair and calibration.

Traditionally, the hospitals needs in engineering staff were covered by converting technical personnel from other engineering fields, mainly electrical, into the necessary specialisations. It is also true to say that until recently the "other engineering disciplines" were the main source of technical personnel in the hospital. Now however, this is not the case and engineering staff are specifically educated for the purpose.

Engineering education at university level, is not yet available locally and Cyprus has to rely on educational establishments in other countries. What is available, is training at technician level at the Regional Training Centre of the Higher Technical Institute whose activities are outlined in this paper.
Being a Medical/Biomedical Engineer in the private sector in a small society such as that of Cyprus, is a title usually associated with either a service or a sales engineer. As far as the duties are concerned, these include installing and maintaining state-of-the-art equipment, without usually, the necessary training. This engineer, would be responsible for the user training and smooth operation of the equipment. Participating in tenders, presenting products to prospective customers and organising exhibitions, are all part of the duties of the medical engineer in the private sector.

Although the duties of the engineer in the private sector are quite demanding, lately there are many young graduates who are seeking employment in this sector. The career opportunities may be a disadvantage compared with that in the private sector, but as the remuneration has changed for the better it is believed that the career prospects will change as well.

THE CYPRUS ASSOCIATION OF MEDICAL PHYSICS AND BIOMEDICAL ENGINEERING (CAMPBE)

Medical Physicists and Engineers engaged in the Health Care Delivery system felt that there wasn't a professional organisation in Cyprus which would represent them and satisfy their professional needs. Individual attempts from both groups to form a recognised association failed because the legal system in Cyprus requires a minimum membership of 21 persons. Negotiations between them, resulted in the setting up of the Cyprus Association of Medical Physics and Bio-medical Engineering in 1987, an umbrella organisation where both groups would be represented on equal terms.

Furthermore, the constitution allows other suitably qualified professionals, such as doctors engaged in research, to become full members or Associates depending on their field of interest and qualifications. Experience so far has shown that these two groups share more common interests than originally anticipated, because in a small country, like Cyprus, the overlap between the professional duties and interests of the two groups is much greater than in other larger countries.

The activities of the Association have been mainly aimed at updating and upgrading the knowledge of its members. These activities involve the following:

- Lectures- These are usually delivered at frequent intervals, on average 7-8 per year and cover the whole spectrum of the health care delivery system.
- Scientific Visits- These are organised on an ad-hoc basis and are mainly organised in conjunction with lectures. These include visits to hospitals, clinics or special purpose installations related to the interests of its members.
- Annual National Seminars- These are annual events and take the form of either a small conference on a specific topic or the form of an open discussion following introductory speeches. Overseas participants and speakers were present in some of these.
- International Conferences - the First International Conference on Medical Physics and Biomedical Engineering was held in May 1994. Participants included 85 persons from abroad. It is worth mentioning that the President of

the Republic opened the work of this conference.

- Participation in Government Committees- The Government of Cyprus has decided to assign to the Association the setting-up and running of a technical committee which will establish National Standards on Medical and Clinical Equipment and Devices.

The Association is a member and has close relations with the following international bodies:
The International Organisation of Medical Physics (IOMP), the International Federation of Medical and Biological Engineering (IFMBE), the International Federation of Hospital Engineers (IFHE), the European Organisation of Medical Physics (EFOMP) and the International Radiation Protection Association (IRPA).

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MEDICAL RADIATION PHYSICS IN THE CZECH REPUBLIC

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SITUATION

The present state of medical departments applying ionizing radiation in the Czech Republic (approx. 10.5 million inhabitants) are described in Table 1. Representative bodies are the Czech Medical Society - Radiation Oncology, Biology and Physics Society and the Nuclear Medicine Society.

TABLE 1: Medical departments applying radiation in the Czech Republic

Type of Department	Number of Departments	Unit Type	Unit No.	No. of Physicists (& other technical staff on MSc level)
Radiotherapy	22	Co/Cs LA B XRU AFL	30/19 8 7 60 11	35
Nuclear Medicine	52	GCC IVA	6055	55
Radio-diagnostics		XRU CT MR	2250 433	5

LA-linear accelerator, B-betatron, XRU-X-ray unit, AFL-afterloading system, GCC-gamma-camera with computer, IVA-in-vivo apparatus, CT-computer tomograh, MR-magnetic resonance.

Comments:

1 The number of diagnostic X-ray units does not include dental units. Because of rapid changes all the given data are approximate and represent the best available estimate.

2 There are no Medical Physics Departments in the Czech Republic. Physicists are usually staff members of the nuclear medicine or radiotherapeutic

departments. Only a few work in radiodiagnostic departments, even if sophisticated equipment is available.

3 Approx. 10 to 12 departments of each of the above type are at the regional level, and they are better and more adequately equipped than the others. Such departments usually employ more than one physicist. Some of the local departments are rather small and their and their future development is endangered by lack of funding.

4 Physicists engaged in at least two or in all three of the above activities, work in five hospitals.

5 About 30 radiation physicists are employed in radiation hygiene institutions organisationally related to medicine.

EDUCATION SYSTEM

Undergraduate studies of radiation physics are not specifically orientated to medical radiation physics at any university. Courses which are closest to the needs of medical departments are offered at the Faculty of Nuclear Sciences and Physical Engineering of the Czech Technical University in Prague. The 5-year degree course consists of two years of basic courses in mathematics and physics, which (referring to subjects important for specialization) also include optional chemistry studies and lay increasing emphasis on computer science and the application of mathematical methods.

Some of the courses related to this basic education continue for yet another year, which is devoted mostly to specialised courses. The list of subjects is given in Table 2. One of the specialisations into which the degree course is divided in the following 3 years is orientated to the dosimetry and application of ionising radiation. These specialized courses begin with a complex course on experimental nuclear physics, including radiation detection and nuclear electronics. Lectures on dosimetry cover basic radiation quantities and their measurements, integrating dosimetric methods, dosimetry in the environment and the workplace, shielding calculations and design, radiation metrology, microdosimetry, etc. Lectures on applications of radiation include applications in industry, science and medicine. Quite a lot of time is devoted to the project work of students, which begins in the 6th semester.

Table 2.

Course	Hours per semester					
	1	2	3	4	5	6
Mathematical analysis	96	104	72	78		
Linear algebra	48	52				
Differential equations			48			
Numerical mathematics				52		
Equations of mathematical physics					72	
Numerical mathematics and statistics					24	26
Monte Carlo methods					24	
Mechanics	72					
Electricity and magnetism		78				
Waves, optics and atomic physics			72			
Theoretical physics				78		
Experimental physics			24	26		
Thermodynamics and statistical physics				39		
Practice on physics (laboratories)			48	52		
Quantum mechanics					72	
English	48	52	48	52	48	52
Other foreign language	48	52	48	52	48	52
Social sciences	24	26				
Review of specialisations			24			
Sports training	24	26				
Further optional and recommended basic courses are included in the 1st to 4th semester (general chemistry, thermodynamics and molecular physics, programming, computer applications, operational systems, etc.						

Table 3: Review of the subjects of the specialised course

Course	Hours per semester					
	5	6	7	8	9	10
Physics of atomic nucleus	24					
Ionizing radiation physics		78				
Solid state physics	24					
Principles of nuclear electronics	24		48			
Principles of dosimetry		78				
Radiation detectors		52				
Nuclear technology devices			24			
Biological effects of radiation			24			
Dosimetry in environment				52		
Applications of radiation			24	52	36	
Physics of radiation shielding				52		
Radiation metrology					36	
Microdosimetry						16
Analytical. methods of measurement				26		
Detection and dosimetry practice			48			
Specialised seminar				26	24	16
Project work		24	48	52		
Diploma project					120	160
Further optional and recommended courses are included, e. g. mathematical methods in dosimetry, radiation effects in matter, dosimetry of internal sources, spectrometry, low level activity measurements, nuclear chemistry, etc.						

The project work continues up to the degree thesis and may be orientated to medical use of radiation, dosimetry in medicine etc., especially in co-operation with some medical departments.

Graduates from other faculties and universities also work to some extent as physicists in medicine. They are graduates from the Faculty of Mathematics and Physics of the Charles University. Faculty of Electrical Engineering of the CTU Prague, the Faculty of the Electrical Engineering of the TU Brno, and in a few single cases also from some other schools. Generally, all the graduates beginning work in the medical departments hold a degree corresponding to MSc.

The postgraduate education system at the university may also include issues of medical physics. As individual plans are prepared for the PhD student, it is possible to tailor their courses and especially individual research projects according to the needs of the medical departments where they are or will be employed. In such cases the PhD thesis must be co-ordinated with these departments and, at least partially , prepared in collaboration with them.

However, there is yet another independent and compulsory postgraduate line of training for physicists working in medicine which is the responsibility of the Ministry of Health. The course is run by the Postgraduate Medical School and this type of education is required by law (Decree No.77 of the Ministry of Health, dated 21 July 1981). The course structure is as follows:-

6 months of introductory medical courses and 2 years of "On-the-job-training", the content varying according to the specializing of the trainee, There is a possibility of optional courses and practical training at the large and well equipped departments. An important part of the course is devoted to radiation protection. Examination are organized by the Postgraduate Medical School and the graduate receives a certificate for "Technical collaboration in radiotherapy, nuclear medicine and radiodiagnosis ", which is recognized by the Ministry of Health. This certificated qualification corresponds partially to the EC demands placed on the Medical Physicist as a Qualified Expert in Radiophysics. A wider comparison with the EC standard would be desirable.

However some problems exists in this line of education, not so much in the content, but in the realisation:

1 The courses are insufficient especially for physicists who graduated at faculties other than FNSPE CTU Prague and for those who work alone in small departments.
2 Examinations are rather formal, chairpersons of the examination boards are always physicians (physicists are only members of the boards). Since 1989, we

have had the opportunity of taking part in some courses and workshops organised by IAEA, ESTRO, WHO, EFOMP, etc, and this has been beneficial to the education and training of Czech medical radiation physicists. There still exist some limitations in participating in such events, but these are due to lack of financial support, not political difficulties. Therefore these events are the most important for our professional societies which are organised in our country or supported by grants. Of course, they can be only supplementary to the regular system of education and training described above, and the improvement of this system must have a high priority.

EXPECTATIONS FOR THE NEAR FUTURE

At present both the medical care and education system in the Czech Republic have been undergoing a rapid transformation and private practitioners are entering this area of activity. Thus to assure high quality of health care and education, good legislative measures are required. New laws regarding public health and higher education are under preparation and they are expected to improve the system of licensing.

Another important bill being prepared just now is the "Atomic Law". Though inspired mostly by the needs of nuclear plants, power engineering and waste disposal, it is intended to be more general and cover all areas of ionizing radiation applications, including medicine.

These new laws - if passed - will certainly influence the system of education and certification of both physicians and physicists in the radiation applying departments. Discussion has been going on, how to design the system for comparison with the EC system, including the demands on and structure of training for the qualified Expert in Radiophysics. These discussions may result in the preparation of the structure summarized in Table 4.

TABLE 4 : Proposed education structure for physicists in medicine

Level	Practice	Demands
I. Basic	up to 1 year	MSc. degree, basic knowledge for work in medical care Qualification: licence 3
II. Medium	1 to 4 years	Licence 3, general training for the specialisation Qualification: licence 2
III. High	4 to 7 years	Licence 2, specialised courses and training Qualification: licence 1
IV. Advanced		Licence 1*, PhD. degree in medical physics or equivalent level

***** Licence 1 corresponds to the Qualified Expert (QEr)

PROBLEMS

Very low salaries of the hospital staff make the career as a medical physicist unattractive. Moreover, the social status of "non-physicians" in medicine is relatively low (see, e.g. the non-existence of specialized medical physics departments even in the largest hospitals). Combined with generally decreasing interest in "nuclear" specialization, fuelled also by unqualified but noisy arguments and activities of various organizations of environmentalists, the result is as may be expected. The interest in studying, e.g. medical physics, dosimetry, radiation protection, etc, has been decreasing and thus there is a shortage of young graduates properly educated and willing to start a career in medicine.

On the other hand, hospitals are not pushed to employ physicists, as they are evaluated (and financed) according to the number of patients and direct diagnostic and therapeutic "output". From this point of view physicists are less attractive members of the staff.

Medical Radiation Physics

As physicists in the medical departments are usually highly qualified staff, it is not difficult for them to find some other employment, far better paid than in the hospitals, especially in private companies. This is the case, of course, and enticing away experienced specialists is thus another danger for these departments.

The personal view of the authors of how to improve the situation is as follows:

- to take legislative measures obliging the medical departments to employ physicists in numbers corresponding to the equipment and number of examinations and/or treatments, taking into consideration also demands for metrology.

- to create a good system of education and accreditation of medical physicists in collaboration between the physical and medical faculties of the universities and the postgraduate schools in the field of health care and to take legislative measures obliging physicists in medicine to pass through this system.

- to increase salaries of qualified staff in hospitals to work systematically for the better status of "non-physicians" in medicine; the importance of modern diagnostic and therapeutic methods must enter the minds of not only specialists, but of all physicians and of the general public.

Unfortunately, we are afraid that this will be a long-term process. In the mean time information on any positive experience of the international community will be appreciated.

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EDUCATION AND TRAINING IN MEDICAL PHYSICS IN DENMARK

K.A. JESSEN[(1)] and K.J. OLSEN[(2)]

INTRODUCTION

The Danish Society for Medical Physics was founded in 1981 and was accepted as a member of EFOMP and IOMP in 1982. The participation in the European and international organisations of medical physicists is particularly important for such a small group as the Danish numbering about 50 hospital physicists. An important goal for the Society has been to establish a forum to take care of the education and training in medical physics in Denmark, and a report was finished in 1985. The basic qualification is a M.Sc. in physics from a University or a Technical University. Due to the small number of hospital physicists required, there has been no possibility to establish institutes for medical physics at the universities and there will not be such possibilities in a foreseen future, therefore the majority of hospital physicists start their first appointment without any previous experience in medical physics.

TRAINING SCHEMES

The Danish Society for Medical Physics recommends a period of minimum three years in-service training in a hospital to become a qualified hospital physicist. The Society has elected a Council for education and training which has the professional competence to approve the individual plans for the theoretical and practical training. The actual department/candidate has to prepare a program report annually. Finally the Council recognize the candidate as a qualified hospital physicist related to either radiotherapy, nuclear medicine or diagnostic radiology. This is in full agreement with the EFOMP recommendations and several candidates are taking part in this scheme at the present time (12). This structure has been discussed with the Danish health authorities and a preliminary agreement was reached in the end of 1991. The agreement to formally recognize the completed training has not come into effect due to problems arising with the biomedical engineers especially about quality control in Diagnostic Radiology. According to ICRP, WHO and now also IAEA the involvement of medical physicists in quality assurance is recommended for Diagnostic Radiology and therefore these problems have to be solved. The biomedical engineers have never been excluded from taking part in the technical aspects of this matter - mostly it is done by external companys anyway. The Danish health authorities has recently confirmed the importance of the educational efforts done by the Society and a revival of the discussions is expected in the near future. The Society of course continue its educational schemes but we are still waiting for a formal recognition of our educational structure and the competence belonging to it, and to our profession as a whole. The national registration scheme with the guidelines will be submitted to EFOMP for formal recognition.

TABLE 1: NUMBER OF HOSPITAL PHYSICISTS

Subject	1: Qualified Hospital Physicists	2. As 1+5years experience
Radiotherapy Diagnostic Radiology Nuclear Medicine	25 3 9	20 3 6
Total	37	29

MEDICAL PHYSICS DEPARTMENTS

All hospital physicists in Denmark are employed within hospitals under the National Health Care system either in Departments of Medical Physics /Radio-physics or as individuals in different clinical departments. All Physics departments are connected to a Department of Oncology and only the largest departments are functioning with some autonomy but none are fully independent. Because the education in medical physics mainly is on-the-job training this system does unbalance the profession as indicated by the numbers of qualified hospital physicists in the different subjects and also paralyse the efforts for further academic education and training to a Ph.D. level in medical physics.

LEGAL REQUIREMENTS

Denmark is a member of the EU and as such has to adjust its national laws and regulations to the EU Directives - in this respect it is the so called Patient Directive and Directive 89/48/EC on "Mutual Recognition of Higher Education Diplomas". As has been mentioned no Danish hospital physicist has an official certificate indicating his competence - therefore he cannot expect to get a position f.ex. in France and the intention of the Directive to facilitate freedom of movement of the various professional groups between countries seems not to be acting. Concerning the Patient Directive a Government Notice on electron accelerators for radiotherapy from October 1991 gives some guidelines about the necessary training for a physicist to get sufficient competence to become qualified hospital physicist. In Nuclear Medicine the term "qualified technical/physical assistance" has been used without any specification of training in a revised Notice from December 1992 - this term was also used in a Notice from before the Directive was active. This concept has been questioned by the Danish Society for Medical Physics for several years.

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Estonia

EDUCATION IN MEDICAL RADIATION PHYSICS AND MEDICAL ENGINEERING IN ESTONIA

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INTRODUCTION

Estonia is the smallest of the former republics of the USSR. It restored its independence step-by step between 1989 and 1991. Its population is 1.5 million and about 1/3 of the population lives in the capital - Tallinn.

The health care facilities are arranged at 3 levels. The radiological equipment is used on the 2nd and 3rd level, beginning from town and district hospitals. The highest, the 3rd level of medical care is concentrated in Tallinn and in Tartu, the second biggest town in Estonia, where the national University is also located. The University has a Medical Faculty, which is the only university-level institution providing medical education.

X-RAY DIAGNOSTICS

There are 118 hospitals and 18 outdoor clinics in Estonia. Most of them have one or two Diagnostic X-ray Rooms. The maximum is 11. The total amount of stationary diagnostic X-ray units in Estonia is about 170. Users: 173 radiologists and 268 X-ray technicians. The equipment is technically supported by approximately 30 service engineers, who are employed:

3 - in local agencies of OEM-s;
17 - in independent service organisations (ISO-s) and
10 - have full or part time jobs as in-house servicemen.

The education of service people ranges from a local electrician (husband of an X-ray technician) to a PhD in Physics. Sixteen of them are Diploma Physicists or Diploma Engineers in a wide range of specialities, but the dominating majority of them are self-educated in Medical Engineering.

Post-graduate education:

1 person has undergone a post-graduate program in a technical university in Moscow as a Medical Engineer,

1 person is undergoing post-graduate education at OEM (Philips) as an X-ray and Imaging Engineer,

3 persons have taken 1-2 two-week courses on principles of X-ray imaging equipment in the USA.

Most of the others have taken some short (1-3 weeks) courses provided by OEMs on certain models of X-ray equipment, mainly related to the production of Russia or former socialist countries. About 35% are totally self-educated or have obtained their experience from their more skilled colleagues. Most of them are *well-educated*, but *poorly trained*, as is typical for previous Soviet republics. It is a good prerequisite for quick development of the people in post-graduate educational training if they should have suitable facilities, teachers and motivation. The best form of education for these people would be hands-on training on X-ray equipment principles, adjustments, service, QA, etc.

There are no specialised medical physicists, involved in radiological imaging, in Estonia today. Their tasks are partly performed by service engineers (20% of them are graduate physicists) and by medical doctor-radiologists.

RADIATION THERAPY

This is concentrated in two oncological hospitals, one in Tallinn, the other in Tartu. The total radiation therapy equipment of these two hospitals consists of: Co^{60} devices - 3pcs; high dose rate afterloading systems - 4 pcs; X-ray therapy devices - 2 pcs; circular electron accelerators (E<20MeV) - 1 pce. 5 radiophysicists and engineers are involved in treatment planning and utilisation of the equipment. 3 of them are Diploma Physicists and 1 of these 3 has PhD degree in physics. Their education in radiophysics consists of 2 months specialisation courses in Moscow and some sporadic participation in 1-week schools and workshops, what is evidently too little. So in general they are self-educated.

NUCLEAR MEDICINE

This is provided by two specialised departments of central hospitals, one in Tallinn and the other in Tartu. The total amount of equipment: 2 gamma cameras and 4 renographs. The equipment is supported by 2 radiophysicists (totally self -educated in Medical Physics) on part time jobs.

RADIATION SAFETY AND DOSIMETRIC CONTROL

QA of radiation equipment is provided by the Department of Radiation Hygiene (DRH)in the body of the National Board of Health Protection. It is located in Tallinn and consists of 7 employees, mostly Diploma Engineers from our technical university. There is a big need for radiophysicists in DRH.

Under the former Soviet regime the radiation control was strictly regulated by laws and regulations from Moscow and therefore accomplished quite regularly. But as all very strict rules, it could not adequately reflect rapid changes in radiation technology and therefore became a bureaucratic formality for hospitals. On the other hand: low salaries and somewhat biased attitude of medical personnel towards the DRH as towards an organisation, which belonged to bureaucratic repressive structures, had prevented qualified radiation specialists from joining this department. Also it has restrained professional development of the employees of the DRH.

Today radiation control and QA is organised on a voluntary basis and hospitals must pay to the DRH for performed measurements. Therefore, at the very beginning of independence from Moscow this work was almost to die out. But today, as the market of health care services becomes competitive, the interest which hospitals take in QA from the side of hospitals has steeply arisen. At the same time it is much more complicated today, compared to the Soviet time, because of :

1 the appearance of Hi-Tech medical equipment, such as CT scanners, MRI equipment, gamma cameras etc. , in the hospitals,

2 widespread use of radiation equipment of different manufacturers and different origin, purchased very cheaply or donated as humanitary aid, sometimes fallen into disuse in their countries of origin because of safety problems. Furthermore, the hard pressures exerted by manufacturers to buy the new equipment and their attempts to discredit the ideas of humanitary aid and the use of refurbished equipment,

3 a) rapid increase of competition in medical services market, which enables the use of QA data for "unfair play" in the competition for patient visits and

b) the introduction of licensing systems for hospitals, which enables to use the data for simplified bureaucratic decisions at licensing procedures if the QA personnel is not enough unbiased and qualified.

4 an almost total lack of equipment for QA measurements in hospitals and the difficulty of obtaining it in the conditions of hard financial restrictions.

Estonia has neither radiation law nor legislative regulations officially in effect today. The situation in radiological medicine needs the creation of these but the reasons mentioned above and the lack of specialists restrain it.

Besides DRH, some other sporadic attempts are made to measure the personnel radiation doses and equipment safety. The most successful is the joint project of the Finnish Centre for Radiation and Nuclear Safety and Universities of Helsinki (Finland) and Tartu (Estonia) - for QA of X-ray diagnostics in Estonia, which began in 1993. As a result of the research, the safety situation is found to be not too bad. The problems are concentrated rather on the quality of accessories (film and screen quality), film processing and the right methods of work by personnel rather than the quality of equipment. Nevertheless, the problems exist in monitoring patient doses during fluoroscopy, which in many cases are too high and uncontrolled. This problem can be divided to 3 "sub-problems":

- lack of trained technical maintenance personnel with adequate knowledge in fixing and adjusting of fluoroscopy parameters and Image Intensifier - TV chain,
- lack of qualified safety specialists to train the medical personnel in proper and safe methods of fluoroscopy and
- absence of suitable dose rate measuring devices.

In conclusion the need for competent radiation safety and QA specialists is evident. The best way would be the post-graduate courses and training for graduates of physics.

EDUCATION SCHEMES

As for general education of Medical Physics and Medical Engineering, there are now 4-5 graduates of Medical Engineering in Estonia. They have graduated from technical universities in Russia. Because of the lack of specialists with such education they were, after graduation, immediately seized for administrative jobs and therefore their influence to the level of medical engineering is very indirect, if at all.

In 1993 the preparations began for a programme of Medical Physics and Medical Engineering in Tartu University and for study of Medical Engineering in Tallinn Technical University.
Now 7 4th year students will supposedly graduate as Bachelors in Medical Physics in Tartu next spring. Some of them will continue their study for two more years to became Masters of Medical Physics. It is possible to get PhD degree in Medical Physics in Tartu after additional 4 years of study.

In Tallinn the undergraduate study has not begun yet, but there are about 13 participants in a programme for Master degree and 6-7 for the PhD degree. Syllabuses for under- and post-graduate study are put together in both Universities (please see the appendix), but both suffer somewhat from the same disease - they are compromises between the completeness of the programme and presence of suitable lecturers. Also it seems that the bridge between these academic syllabuses and practical Medical Physics and Medical Engineering is narrow. Nevertheless there is enough reason to think about cooperation with other countries in the preparation and the exchange of lecturers for biomedical disciplines.

As with the other forms of post-graduate study, there have been some short workshops about processing of bioelectrical and physiological information, organised and under the sponsorship of OEMs and the other vendors of medical equipment; some 2-3 day seminars on radiology, addressed mainly at medical doctors - radiologists, etc. This kind of post-graduate education has been quite random, possibly because of small amount of people, involved in certain narrow specialities. The same situation will apparently go on in future as well because of smallness of the population of Estonia. This causes our special interest in international contacts and cooperation in post-graduate study.

REPRESENTING BODY

The **Estonian Society for Medical Engineering and Medical Physics** (ESMEMP) was founded in January '94 and now has 52 personal members (about 1/3 of them being medical doctors). In the future the ESMEMP will cover the implementation of such workshops and courses, mentioned above. The first workshop (about the processing of blood flow data and ECG) will be held in Tallinn at the beginning of November. The ESMEMP will also present Estonian medical physicists and biomedical engineers in international organisations. It is already accepted by the IFMBE and joining with IOMP is now under discussion.

CERTIFICATION AND RECOGNITION OF THE PROFESSION

Today Estonia has no certification programs for biomedical disciplines, so there is no mechanism for those who have reached significant levels of competence to be formally recognised. In the conditions of insufficient QA; significant amount of vacancies in biomedical professions; wide use of renowned equipment and great variances in the background of professionals, the absence of the certification system leads to a situation, where less qualified people are significantly overpaid and more qualified are underpaid. This fact, in its turn, has the tendency to stabilise the situation of incompetence. The situation is made worse by the fact that medical managers, who are usually employers of medical engineering staff, are representatives of medical professions which are quite different from engineering. Therefore they cannot, in many cases, value adequately the professional level of their technical co-workers. They need some qualified and unbiased support in this. Because of the small amount of people involved in Estonia, we need obviously international collaboration in the certification process either in the form of some specialization between the countries or exchange of certification programs and questionnaires. Both solutions need setting up of some international standards in the quality of certification. Sufficiently unified general education schemes in post-socialist countries form a good basis for such kind of cooperation. In Estonia the process will be supposedly carried out under the control and coordination of ESMEMP and the interested members of this Society.

In summary the Medical Physics and Medical Engineering staff in Estonia is involved in:

2 universities;
2 oncological clinics;
1 Department of Radiation Hygiene;
3 ISO-s;
2 local agencies of OEM-s;
9 research and design groups, laboratories and companies (some of these groups are independent and some are included in the body of the other institutions).

Totally Estonia accounts for 19 institutions of Medical Physics and Medical Engineering, the number of employees mainly 2.3, the maximum ca 30 (dependent on criteria, we set up to separate Medical Engineers from Medical "non-Engineers"). The total number of Medical Physics and Medical Engineers in Estonia is about 100, with great variances in background, competence, their way into Medical Engineering, self-cognition as Medical Engineers, affiliation to societies, affiliation to occupation field (such as research, education or technical support) etc.

CAREER OPPORTUNITIES

Opportunities are good in Medical Engineering in Estonia due to the fact that whereas under the Soviet regime Health Care was the last branch of the economy where new technology was introduced, in western countries it seems to be the second (after military) or the third (after military and science). This has generated a gap in Medical Technology between Estonia and the advanced countries. Therefore the introduction of modern technology into health care in Estonia is very rapidly filling this gap and there are quite clear signs of "overheating" in this branch of economy. One of the results of "overheating" is the fact, that the education of the people involved, cannot meet the needs of the technology introduced. It causes a lot of potential vacancies, lot of jobs filled with people with inadequate competence, thus leading to misuse of equipment, low quality purchasing decisions etc. Today we have 8-10 clinical physicists and engineers who have obtained significant level of experience in self-education and they all have 3-5 job offers from different companies, governmental and educational institutions, but essentially their education has remarkable "holes". The most important way to overcome the difficulties is wide use of different kinds of post-graduate education, combined with undergraduate education in medical physics and medical engineering, what has recently begun in Estonia.

FUTURE NEED FOR MEDICAL PHYSICISTS AND ENGINEERS

Supposedly the number of people involved in Medical Physics and Medical Engineering will not increase remarkably in Estonia in the future, but the professional level of competence will increase rapidly after 2-3 years. Today the decision makers in hospitals are occupied in obtaining the new technology, after this relaxation time they supposedly will feel the need for proper handling and maintenance of this technology and thus the need for investment into professional development of Medical Engineers and Medical Physicists will increase. The professional and educational sectors in Estonia must be ready to satisfy the need.

Supposed changes in the nearest future in these professions will be:

a)clearing the borders between different adjacent professions (e.g. between clinical physicists and clinical engineers, between imaging and physiological equipment specialists etc.),

b)increasing the share of radiological and imaging professions among the other technical professions in health care,

c)increasing the number of teachers and safety specialists/consultants.

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Appendix

TARTU UNIVERSITY, Faculty of Physics & Chemistry
Syllabus for upper stage of undergraduate study.

Main Subject: Physics
Sub-speciality: Medical Physics and Biomedical Engineering.
Obligatory to gain in upper stage of undergraduate study: 53 CU consisting of:

1.	Obligatory courses from section A	23 CU
2.	Elective courses from section B	6-10 CU
3.	Free courses - social sciences	5 CU
4.	Free courses - professional	2 - 6 CU
5.	Thesis, written to obtain Bachelor Degree	13 CU

A.	**Obligatory courses (23 CU)**	Hours /	Year Semester	CU
1.	Introduction to metrology	16	2 - 1	1
2.	Basics of information theory	32	2 - 2	2
3.	Control and measuring systems	64	3 - 2	4
4.	Digital electronics I	32	4 - 2	4
5.	Digital electronics, training	32	4 - 1	1
6.	Introduction to visualisation of biological objects and processes	32	4 - 2	2
7.	Biomedical signals and measuring methods	64	4 - 4	4
8.	Anatomy and physiology	64	4 - 1&2	4
9.	Medical biomechanics and modelling	32	4 - 2	2
10.	Functional morphology	32	3 - 2	2

B.	**Elective courses (6-10 CU)**	Hours/	Year Semester	CU
1.	Methods of NMR in physics and chemistry	32	3 - 2	2
2.	Non linear circuits	32	4 - 1	2
3.	Planning and analysis of experiment	48	3 - 1	2
4.	Digital electronics II	24	3 - 1	1
5.	Metrology of non-electric parameters	32	4 - 4	2
6.	Human biology	32	4 - 1	2
7.	Laser physics	32	4 - 1	2
8.	Dosimetry	32	3 - 2	2
9.	Processing of analogue signals	32	4 - 1	2
10.	Radiations in medicine and their measuring	32	4 - 4	2
11.	Biomechanical diagnostics of skeletal muscles	32	4 - 1	2

Estonia

TARTU UNIVERSITY, Faculty of Physics & Chemistry
Syllabus for Master's Degree

Main Subject: Physics (80 C.U.)

Sub-speciality: Biomechanical Engineering and Medical Physics

1.	Free courses in general physics	6 CU
2.	Free courses in mathematics & computer sciences	4 CU
3.	Free courses in natural & humanitary sciences	4 CU
4.	Special courses from the list below	16 CU
5.	Master's examination in physics	4 CU
6.	Thesis, written to obtain Master's Degree	46 CU

Special courses in Biomedical Engineering and Medical Physics

1.	Theory of random functions	2 CU
2.	Basics of physical metrology	2 CU
3.	Programming language C	2 CU
4.	Methods & equipment of medical diagnostics	2 CU
5.	Methods & equipment in therapy	2 CU
6.	Biological Substances and replacement composites	2 CU
7.	Orthopaedic devices and prostheses	2 CU
8.	Biomechanics of functional systems	2 CU
9.	Radiation dosimetry	2 CU
10.	Mathematical methods in biological medicine	2 CU
	Obligatory to gain	*16 CU*

Medical Radiation Physics

TALLINN TECHNICAL UNIVERSITY
Syllabus for Biomedical Engineering

The special courses are considered for students with different background: electrical, mechanic, computing systems etc. engineering. Courses of group A are mainly predicted for undergraduate study. B are mainly predicted for postgraduate study:

		Semester	Total hours	Lectures-laboratory exercises	CU
A.	**Obligatory**				
1.	Fundamentals of physiology and nerve activity	2	3	2-1-0	2.5
2.	Biomechanics	1	3	2-0-1	2.5
3.	Electromagnetic waves in biological tissues	2	4	3-1-0	3.0
4.	Medical signal processing	2	3	2-1-0	2.5
5.	Medical imaging	1	4	2-2-0	2.5
B.	**Electives (minimum 6.5 CU)**				
1.	Computed tomography	2	4	2-2-0	3.0
2.	Radiothermography	1	3	2-1-0	2.5
3.	Mathematical modelling of physiological signals	2	3	2-0-1	2.5
4.	Medical ultrasound	2	4	2-2-0	2.5
5.	Bioelectromagnetism	1	4	3-0-1	3.0
6.	ECG, EEG	1	3	2-1-0	2.5
7.	Thesis in Biomedical Engineering				
				Total	30.0CU
		Obligatory to gain		*6.5CU*	

MEDICAL PHYSICS IN FINLAND

G.T. KUIKKA [(1)]

STATUS

The first hospital physicist started work in 1937 at Helsinki University Hospital. Nowadays there are about 60 hospital physicists in Finland who are working in different fields of medical physics i.e. in clinical physiology, in clinical neurophysiology, in nuclear medicine, in radiology (including NMR), in radiotherapy as well as in radiation safety. The majority of them are involved in radiation physics.

There is only one Medical Physics Department in Finland (at Tampere University Hospital) due to the fact that the hospital physicists are scattered into several clinical or diagnostic departments. However, the chief physicists (nine in the country) have considerable independence to lead their physicists.

EDUCATION

The educational and training background for the degree of hospital physicist has been recently renewed. The minimum university degree is Ph.L. (analogous to M.D.) which usually takes 6-7 years to complete. There is 4 years job in training (as an assistant physicists) in a teaching (university) hospital under the guidance of the chief physicist. In addition there are 2 written examinations, one for the competence of hospital physicists and one for radiation safety. The National Board of Training and Education (under the Ministry of Education + the Ministry of Social Health) in Hospital Physics supervises this training, courses, competencies etc.

Post-graduate courses (5-6 days) are organised nationwide 1-2 times per year. Shorter (1-2 days) courses together with medical doctors are much more frequent. There are also local weekly seminars as well as courses in hospital administration etc.

There are 4 ranks in hospital physics; assistant physicist, hospital physicist, assistant chief physicist and chief physicist. Their salary classes are equal to those ones of the corresponding physicians. More than 1/3 of the Finnish hospital physicists have a competence of professor or docent in Medical Physics or in equivalent fields.

The profession of the hospital physicist is recognised by the Finnish bylaw.

This means that no one else than the competent hospital physicist can be taken into full-time job in a given hospital. Career opportunities have been rather good but may come heavier in the coming future. On the other hand there are several physicists who will retire soon which will open new posts for younger hospital physicists.

Research and scientific activities of the Finnish hospital physicists are better than the average. But - more professional scientific way to do research has to be taught into our brains. Of course there is lack of time to do research and some suggestions have been done. One generally used solution is a research hospital physicist (free from daily routine for 3-6 months) which allows to concentrate for scientific activities.

Future need for medical radiation physicists is not increasing heavily, the estimation being that 3-6 new positions within the next 5 years will be the maximum. However, in other fields of medical physics (in NMR, in clinical physiology, in clinical neuro-physiology etc.) there is a greater demand. There are also several engineers and other specialists (in computer science) who partly apply their skills in medical physics.

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RADIOLOGICAL AND MEDICAL PHYSICS IN FRANCE

A. NOEL[(1)] and B. AUBERT[(2)]

INTRODUCTION

In France, Medical Physics is practised by scientific specialists who must have received a specific postgraduate training both theoretical and practical. The working field of the Medical Physicist, Hospital Physicist or Radiation Physicist as called in France cover the use of ionising radiation mainly in radiotherapy and now entering nuclear medicine and radiology. All figures in this report are as at 01/01/93.

The presence of a medical physicist has been imposed in radiotherapy since 1969 and in departments of nuclear medicine since 1988. In these cases the profession is regulated and an agreement procedure has been drawn up stipulating qualifications for hospital physicists which became law in 1977.

HOSPITAL PHYSICIST

All physicists have a postgraduate degree in radiology and medical physics and about 2/3 get a higher academic qualification i.e. Ph.D. At present 220 hospital physicists work in radiological physics, 92% working exclusively or primarily in Radiotherapy, 6% in Nuclear Medicine and the remaining 2% in Radiology. Following the EFOMP policy statement 3/4 of French physicists can be considered as qualified experts in radiophysics. Many hospital physicists are also designated as qualified experts in radiation protection.

It has to be stated that few medical physicists have research activities and/or training responsibilities but no hospital physicists has an academic position in France unlike in some other countries.

RADIOTHERAPY

In France there are 204 Radiotherapy departments, 116 having brachytherapy facilities. Radiotherapy is performed either in a public service (Hospital) or in private practice or in Cancer Centres which have a particular status. There are 76 departments in Hospitals, 107 in private practices and 20 Cancer centres. These radiotherapy departments use 163 cobalt units and 195 high energy linear accelerators as shown in table 1.

France

TABLE 1: Distribution of the treatment machines as a function of the departments' status

	Cobalt Units	Accelerators	Totals
Private Practice	82	87	169
Hosital	47	60	107
Cancer Centre	34	48	82
	163	195	358

It is interesting to indicate the constitution of the medium sized radiotherapy department:

* Private practice: 50% use 1 treatment unit (cobalt or accelerator), 40% have 2 treatment units (1 cobalt unit and 1 linear accelerator) with 1 Medical Physicist in most cases.
* Hospital: 25% have 1 treatment unit (cobalt or accelerator), 55% use 2 treatment units (1 cobalt unit and 1 linear accelerator), 10% have 3 treatment units (1 cobalt unit and 2 linear accelerators) with 1 Medical Physicist in most services
* Cancer Centre: 75% have 4 treatment units (2 cobalt units and 2 linear accelerators) with 2 Medical Physicists.

TABLE 2: Number of medical physicists per radiotherapy department

	1 Phys	2 Phys	3 Phys	4 Phys	5 Phys
Hospital	41	11	3	2	1
Private Practice	68	12	1		
Cancer Centre	2	12	5	2	1

TABLE 3: Number of medical physicists per treatment unit

	Machine	Physicists	Ratio
Hospital	107	85	0.8
Cancer Centre	82	56	0.7
Private pactice	169	95	<0.6

Actually very few Medical Physics Departments have been set up in France. At present there are about 13 Medical Physics Departments of which there are 10 in Cancer Centres and 3 in Hospitals.

NUCLEAR MEDICINE

In 1993 there were 159 nuclear medicine departments with the following distribution: 11(63.5%) for public or university hospital, 19(12%) for cancer centres and 39(24.5%) for private institutions. The number of installed gamma cameras was 321 corresponding to 1 camera per 170,000 inhabitants. The number of cameras per department is indicated in table 4. There were 196(61%) cameras in public or university hospitals 72(22%) in cancer centres and 55(17%) in private institutions.

TABLE 4: Distribution of nuclear medicine departments versus number of gamma cameras in France

Number of Cameras per department	1	2	3	4	5
Number of departments	49	51	30	15	4

In 1994 the number of medical physicists working mainly, or exclusively in nuclear medicine is 6 in public or university hospitals, 7 in cancer centres and 1 in private institutions.

DIAGNOSTIC RADIOLOGY

In diagnostic radiology there now does not exist legal requirements for the services of a physicist. However, there is currently a proposal under consideration that radiology departments should be included in article 5 of the European directive 84/466/EURATOM as radiodiagnostic is the largest contribution to radiation exposure in medicine.

Without considering the way practices are structured there are approximately 22,000 x-ray tubes (includes radiographic, fluoroscopic, tomographic, mammographic, portables and CT units), 35,500 dental units and very few physicists. Only 1 or 2 Medical Physicists are working exclusively in diagnostic radiology. Although the number of sophisticated machines (table 5) and the necessity of quality assurance for screening in mammography justify the needs of these experts in diagnostic radiology departments.

TABLE 5: Number of sophisticated machines in diagnostic radiology departments in France

CT Scanner	M.R.I.	Digital Radiology
430	80	457

SOCIETE FRANCAISE DES PHYSICIENS D'HOPITAL (SFPH)

Founded in 1972, the French Society of Hospital Physicists (SFPH) is a scientific association for all those who have an interest in Medical Physics. The SFPH aims to promote the professional, academic and social communication between its members.

Each year the French Society of Hospital Physicists organise an annual meeting which takes place at the beginning of June and 2 teaching courses on various subjects of interest in Radiotherapy, Nuclear Medicine or Diagnostic Radiology.

The scientific work of the Society is dealt with within the committees such as Linear Accelerators, Diagnostic Radiology, Computer in Radiotherapy, Quality Assurance of the Radiotherapy Treatment, Quality Assurance in Digital Imaging, Quality Assurance in Nuclear Medicine and Ethical and Professional matters. The work of these Committees is published by the Society.

THE FRENCH MEDICAL PHYSICIST TRAINING

The education of Medical Physicists in France can be divided into 3 stages:

* First stage: Entrants to medical physics should have, as a minimum requirement, the Master of Science, or its equivalent.

* Second stage: One year is required. The purpose is to introduce Medical Physics in the form of an academic program for postgraduate degree in Radiological and Medical Physics. At the beginning of this period 200 hours of formal courses are given followed by 6-months research work. Some students are supposed to reach a higher academic level in defending a thesis

to obtain a doctorate in radiological physics.

* Third stage: This step is in-service training in hospitals. The in-training program is aimed at providing both education and practical experience simultaneously. This stage includes mandatory formal courses, practicals and an hospital-based medical physics training. In-Service training is done in an accredited physics department under the supervision of a senior medical physicist i.e. with a Ph.D. degree. All aspects of radiological physics (Radiation Therapy, Nuclear Medicine and Diagnostic Radiology) should be taught. The length of this is 1 year.

After finishing this the student is recognised as a medical physicist and can apply for the agreement delivered by the Ministry of Health, a compulsory procedure to be able to get a place as a hospital physicist in France.

FUTURE NEED FOR HOSPITAL PHYSICISTS IN FRANCE

There are 3 hospital physicists per million inhabiltants in France, ranking just ahead of Portugal which has only 2 physicists per million, lagging far behind the other countries of the European Community.

Ultimately a majority of medical physicists practice their activity in radiotherapy and each year 170,000 radiotherapy treatments are performed. Taking only this field into account and if we look at the different recommendations there is already a dramatic lack of physicists in France (without mentioning the shortage in nuclear medicine and diagnostic radiology).

Considering the figures of the ESTRO, laying down that 1 qualified medical physicist is needed per 600 patients, 280 physicists are required. Following the EFOMP recommendations about 550 hospital physicists will be needed. At the present time there are only about 165 qualified experts in radiophysics in France.
In nuclear medicine according to a report of the SFHP based on the recommendation of the EFOMP and the AAPM we can estimate the needs for medical physicists working mainly in nuclear medicine between 50 (all departments with at least 3 cameras) and 120 (all departments in public or university hospitals and in cancer centres).

Finally, if we apply the criteria given by EFOMP (1 physicist per 500,000 inhabitants) for the number of physicists in a diagnostic radiology departments utilizing a full range of techniques about 120 radiological medical physicists will be required. According to the IPSM criteria the needs in medical physicists would be about 2000.

To summarise, this means that between 115 and 385 physicists have to be trained just to satisfy the demand in radiotherapy and more if we are considering the need in nuclear medicine (50 to 120) and diagnostic radiology departments (120 to 200).

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EUROPEAN SCIENTIFIC INSTITUTE

Y. LEMOIGNE(1)

INTRODUCTION

The European Scientific Institute (ESI), established on the border between France and Switzerland, is devoted to high level post-graduate teaching needed for the transfer of the latest technologies between Research and potential users like Medicine for instance.

The first idea of something like ESI came from the fact that it is very difficult for a small university to have a number of students large enough to organise high level teaching in very specialised fields like Accelerator Technologies, for instance. A typical example was Norway, in the University of Bergen, it would be possible to find each year one or two students wishing to follow specialised Accelerator courses. There are three Universities in Norway. At national lever, the total number of students would not exceed half a dozen. Such specialised courses would need much more lecturers then students!

The only solution would be to organise such courses at a European level. As most of the experts in this field are often present in Geneva, an appropriate locations would be the Geneva area, but inside European Union territory, so as to take part in the ERASMUS or TEMPUS university European programmes (including financial help from European Union to exchange of students or lecturers).

PRINCIPLES

The European university academics who have been working on the project have emphasised the need to respect four principles:

- ESI will only offer subjects that are not already being taught elsewhere at the envisaged level and in the same form. In effect, its purpose is to provide tuition on highly specialised or rapidly evolving subjects, which are proposed by the universities.
- It will use the skills available in the Geneva area or connected with it (CERN, Hospital Cantonal de Geneve...)
- It can operate only with the fullest European involvement. The aim is to strengthen European universities and laboratories by enhancing the level of skills.

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- The administrative link with the home institution will be maintained as the institution itself is a member of ESI.

- A fifth principle can also be underlined, namely a "flexibility" principle allowing students to choose any number of 3-month (or less) units from a normal 9 months year, and possibly shared over different years.

The Institute offers a unique opportunity of bringing the students of many nations together. This creates a more stimulating environment than the binary exchange which is the current practice through the European Union programmes.

STUDY LINES

Many study lines have been suggested by the universities involved in the setting up of the Institute. In the first priorities are an Accelerator Technologies teaching program and a Biomedical Physics Development study line covering the domains of detectors, imaging and accelerators. There are some obvious connections between these two study lines. Teaching staff will be under contract with the Institute for a limited period.

Accelerator Physics + Associated Technologies

In this domain, the Geneva area benefits from the expertise of the many physicists and engineers of CERN and of the close-by centres of ESRF in Grenoble, and PSI in Zurich, in a number largely exceeding what universities can offer. This study line was operational early in 1994. The next session will take place from 9th January - 24th March 1995. Coordinator of this study line is Dr M. Rey-Campagnolle.

Biomedical Radiation Physics Teaching

With specialised courses in Biomedical Physics, one aim of ESI is to give access to top level knowledge which will allow the physicists to apply and further improve, inside their home institution, the latest developments of detectors, imaging and accelerators for use in fields like Diagnostic, Nuclear Medicine and Radiotherapy. This will clearly be complimentary to already existing teaching in some European countries at graduate or postgraduate level. The courses will help to satisfy the requirement for high level radiation physicists which is continuing to increase mainly for development of new detectors allowing less irradiation, Medicine Imaging techniques and new uses of accelerators. Coordinator of this study line is Dr Y. Lemoigne.

European Scientific Institute

WORKSHOP

To prepare the definition and the practical organisation of the study line, a workshop has been held at mid-October with the participation of some experts (14 nationalities were represented). In parallel, a detailed investigation about present teaching of Biomedical Physics in Europe and future needs has been done using the channels of the national representatives inside the European Federation of Organisations for Medical Physics (EFOMP). We obtained answers from 18 countries.

The workshop was organised in three parts: First there was a review on emerging technologies in accelerators, detectors and imaging, which could be useful in Medical Physics in the coming years.
There was then a review of training, teaching and needs for Medical Physics in some European countries. The third part was devoted to discuss how ESI could fulfill these needs, at least partially.

The workshop has retained an organisation of three levels:

Level 1:
The highest would be one week devoted to only one topic which will be intensely studied (symposium type). The public addressed will be senior medical physicists and the heads of Medical Physics. It is foreseen to start as soon as Easter 95 with "Medical Imaging and new types of detectors". Other topics could be (for example):
- Conformal Radio-Therapy
- Functional Imaging
- Algorithms and Mathematics for Imaging
- Dosimetry and Mathematics for Imaging
- Quality Insurance in Radiology and Radiotherapy
- Radiopharmaceutics
- Non-Ionising Biomedical Diagnostics

Level 2:
These will be high level courses aimed at advanced post-graduate students or physicists wiling to specialise in Medica Physics. True multidisciplinarity will be necessary i.e. well balanced basic and clinical research programmes. A typical topic could be: "Accelerators for Nuclear Medicine, Diagnosis and Therapy". About 150 lectures (4-5 weeks?) are foreseen.

3.3 Level 3:
These will be basic courses in Medical Physics. The demand was expressed

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urgently by some countries that need some help to start a post-graduate training programme.
The present scheme foresees a teaching programme organised in three terms mixed with practical sessions. A part of the practical training will be programmed in expert centres under ESI co ordination.

The workshop has retained the principle of three levels gradually put in place: two one-week-symposia in 1995 (Level 1), a module of High Level Courses (Level 2) in 1996 and Basic Courses (Level 3) later.

4. CONSTITUTION OF ESI

ESI has been created as an association based on the French Law of 1901 which is commonly used. It is an highly flexible structure which applies to association with a non-profit aim. As such, it perfectly suits ESI's purpose. As soon as regulations will allow, ESI will become an European Association (the European Union is preparing such regulations).

The members of the Association can be Universities of Research Institutions, companies, private societies, local public authorities and bodies in Europe that are automatically entitles to membership by virtue of their contributions to the operation of the Association. The Association was set up early 1994.

Members

- Centre Universitaire et de Recherche d'Archamps:\archamps (France)
- II Faculty, of Sciences, Uni. of Milano at Como: Como (Italy)
- Universite de Geneve: Geneve (Switzerland)
- Institute of Theoritical and Exp. Physics: Moscow (Russia)
- Moscow Physical and Technilogical University: Moscow (Russia)
- IN2P3-LAPP : Annecy-le-Vieux (France)
- Universite Charles : Praque (Czech Republic)
- Uppsala University : Uppsala (Sweden)
- University of Mines and Metallurgy: Krakow (Poland)
- A Commercial Company: Compact Detector System (C.D.S): Thoiry (France)

The present Association is open to Universities willing to join.

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MEDICAL PHYSICS IN GERMANY

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INTRODUCTION

The Deutsche Gesellschaft fur Medizinsche Physik DGMP (German Association of Medical Physicists) was founded in 1969. The former GDR hospital physicists working in the field of ionising radiation had formed a section "Clinical Radiation Physics" within the former Society for Medical Radiology of GDR. Physicists engaged in non-ionizing medical physics were associated in a section "Medical Physics" which in fact aimed to cover the total spectrum of physics applied in medicine, and in so far has been comparable to the DGMP which for the time being represents about 1200 members. Our society publishes the monthly journal "Medizinische Physik" (Medical Physics).

GENERAL REMARKS ON MEDICAL PHYSICS AS A PROFESSION

In Germany Medical Physics is considered in a more general sense as a branch of Applied Physics which according to the definition of MAYNORD at the first International conference of Medical Physics 1965, deals with any application of Physics in Medicine. The interdisciplinary character of Medical Physics is not only obvious in its bridge function between Physics and Medicine, moreover Medical Physics is integrated in a network of natural and biosciences such as mathematics, chemistry, biology, computer informatics, biophysics, bioengineering. Slightly different to some other countries we consider Medical Physics to cover a number of other branches or sub-specialities like radiation physics, laser physics in medicine, physiological measurements, etc. This interpretation of Medical Physics is the essential base of the DGMP-qualification concept outlined in the last part of this paper. Each year the German Association of Medical Physics arranges a scientific congress. The last conference was in Erfurt in September this year.

WORKING CONDITIONS OF MEDICAL PHYSICISTS IN GERMANY

Based on the results of a general inquiry performed within the DGMP in 1990 the present situation of the medical physicists can be described in detail. However, limitations of this inquiry have to be taken into account in so far as the DGMP members are predominantly (ca 70%) working in radiation physics, whereas especially physicists engaged in other specialities (laser, physiology, ophthalmology etc) are more often affiliated to the corresponding medical associations. Concerning the qualifications of German medical physicists we found 85% with university degree in physics or a technical college (diploma), 59% with a doctor-degree and 17% with an appointment as university lecturer. At very few institutions (Berlin, Heidelberg, Hamburg) postgraduate studies in Medical Physics have just been initiated, demonstrating that training in Medical Physics typically does not get started prior to a complete physics study at a university. Medical physicists. 38% are most often appointed to radiotherapy, nuclear medicine, more rarely to radiation diagnostic departments in universities; other 30% are working at community hospitals, 14% in industrial companies, the rest in other institutions (research, administration etc). Interesting to note is that there is a continuous relative increase of positions for medical physicists in hospitals compared to universities reflecting mainly the increasing number of radiotherapy units and the significant spread of sophisticated equipment such as accelerators, treatment planning etc, in the domain of routine cancer treatment. It has to be emphasised that 50-70 medical physicists will be needed per year in the future.

The **Table** below shows in more details, for the different fields of Medical Physics, the first and the second priority of our medical physicists.

Field	**1st priority (%)**	**Next priority**
radiotherapy	48.8	7.0
nuclear medicine	10.0	13.5
X-ray diagnostic	10.8	17.6
radiation protection	9.2	30.5
computer informatics	1.2	8.8
other fields	20.0	22.6

The fields corresponding in the general inquiry within the DGMP in 1990 are:
aerosol research - audiology - biophysics - biomechanics - biosignal analysis - research organisation - MRT, MRS - medical laboratory - lithotripsy - medical optics - medical physics (common) - medical technique - neurosurgery - physiological measurements - radiation biology - immersion medicine - ultrasound - administration.
About 70% of members are working in the 3 most important radiological fields. In the **Table** below (including only the old federal countries) the institutions are listed where medical physicists are working:

Designation	**% of all 677 members of DGMP (inquiry 1990)**
university clinic	38
Community hospital	30
research institution (without university)	5
administration	8
industrial firm	14
others	5

Still today it is the most frequent structure of Medical Physics to be an integrated part of the respective medical section. In so far all efforts of DGMP are aiming at a more independent and separate structure Medical Physics should be organised in the medical environment. According to the recent DGMP-inquiry only every 7th medical physicist is working in a separate medical physics department, whereas nearly 40% are indicating to be organised in a medical physics unit being independent to a certain degree only; finally, every second medical physicist is working as a member of a small group not at all separated from the medical section.

Considering the growing importance of physics in all medical fields the organisational structure of medical physics should comply with this trend; otherwise a lack of high level physicists is preprogrammed for the future which in fact will have serious consequences for the standard of medical physics itself, for the education and training level and not least for the whole health system. Therefore, DGMP feels the structure of medical physics at the universities and larger hospitals has to be a key issue for the future, not only in Germany. Departments and sections for Medical Physics are essentially the pillars of a qualification system in our profession which in fact is another main DGMPgoal.

THE DGMP PROFESSIONAL QUALIFICATION SCHEME IN MEDICAL PHYSICS

Stimulated by WHO demanding in 1972 a training program in Medical Physics, and supported by the German federal health advisory board, DGMP set up its first professional qualification scheme in Medical Physics in 1974. Since then DGMP is undertaking all efforts to get an official state approval for this qualification scheme which due to formal legislative problems is still on the way with the exception of the federal country Berlin. However, the federal and

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state governments are aware of the need to come up with a solution of the problems, at least in medical radiation physics where the EEC-directive 84/466/Euratom is claiming the availability of a "qualified expert" in radiophysics in sophisticated departments of radiotherapy and nuclear medicine.

GENERAL RULES OF THE DGMP-QUALIFICATION SCHEME:

a) The entrance qualifications are a first degree in the area of physics from an institute of higher education or a technical college (diploma), which entitles the person concerned to commence a doctorate. The further training comprises a professional activity in Medical Physics.

b) Qualification as a medical physicist needs to prove professional activity in medical physics under supervision of a qualified medical physicist for at least 3 years.

c) Totally 360 hours training courses in Medical Physics have to be completed. This acquisition of theoretical knowledge is split into three phases nearly equivalent in time:
Basic Courses - fundamental knowledge in anatomy, physiology, biochemistry, biomathematics, biophysics, informatics, biomedical engineering, public health care.
Courses in special branches -thorough knowledge and practical experience in one area of Medical Physics contained in the DGMP-prospectus.
Courses for various fields - basic knowledge in two or three additional areas of Medical Physics according to the subject matter catalogue prospectus.

The DGMP has produced a prospectus for further training, in Medical Physics which is regularly updated by the committee at the DGMP responsible for further training. All important decisions in the procedure for the granting of professional recognition are taken after consulting the applicant's tutor, and are explained to the applicant.

A tutor is usually the medical physicist employed at the applicant's place of work, who is authorised by the DGMP to provide further training. If a person's professional activity is undertaken at a place of work where no medical physicist authorised to provide the training is employed, the approval committee must, on request, appoint a tutor. Tutors support further training by :

- means of frequent contact with the applicant;
- examining the physical, technical equipment of the place of work;

- talking to superiors and colleagues of the applicant;
- giving advice in the planning of training and the selection of courses and lectures.

Successful completion of the whole qualification scheme is attested by the granting of a recognized professional qualification in Medical Physics which authorises a person to add to his professional title the words "with a recognised professional qualification in Medical Physics (DGMP)" and an addendum "field medical radiation physics or "field audiology".

When DGMP initiated activities in setting up the qualification scheme its adjustment to the EFOMP policy statements was a major concern. We are sure we could attain this goal fairly well, supporting the idea of a uniform, high level education and training in medical Physics in Europe.

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MEDICAL PHYSICS EDUCATION IN GREECE

B. S. PROIMOS[(1)]

STATUS

In 1956 two physicists were appointed in the "Alexandra Hospital" of Athens, to work for the first Greek Laboratory of Nuclear Medicine and one of the first teletherapy installations equipped with a Cobalt-60 unit. Following their appointment these two first physicists were educated in Medical Physics by attending several seminars organized by international organizations, such as the IAEA and by studying books and papers.

In 1959, the writer returned to Greece from MIT (Cambridge, U.S.A), where he was awarded a M.Sc. Degree and he was trained in the Physics of Radiotherapy. He was appointed as the first medical radiation physicist in the Greek Anticancer Institute, which was then the only cancer Hospital in Greece.

From 1961 to 1982 the School of Hospital Physicists, organized by the Greek Atomic Energy Commission at the Nuclear Center "Dimokritos" educated a total of about 70 Medical Radiation physicists.

From 1960 to 1994 about 50 Medical Physicists educated abroad mainly in U.K. and France to an M.Sc degree level, have returned home and they are employed mainly in Greek Hospitals.

This way, the Greek Association of Physicists in Medicine has now about 125 members.

EDUCATION IN THE UNIVERSITY OF PATRAS

From 1989 to 1994 a Course on Medical Physics (MP) and Biomedical Engineering (BME) organized through ERASMUS at the University of Patras is implemented annually. About forty Greek medical physicists were educated through this course. Most of them are now under practical training, in order to be eligible for the State License Examination. This way, they will obtain the License to practice Medical Physics in the hospitals of Greece.

This double Course on MP and BME is now supported by one ERASMUS and two TEMPUS projects. This year (1994-95) 14 Romanian and about 10 Bulgarian students are joining the students coming from the Countries of European Union.

The policy and structure of this Course is presented in the following:

The Course is entirely given in English
No more than fifty students are admitted
A Course teacher acts as a coordinator in each of the participating Universities. He/she is responsible for evaluating and selecting the students of his/her University as candidates to be sent to Patras.
The students must speak English and they must posses adequate knowledge of Physics, Mathematics and Electronics to follow the Course.
Preference to admission is given to students who apply for the whole Course and who hold a Degree in Physics, for the Medical Physics (MP) part or a Degree in Electrical or Electronic or Computing or Mechanical or Chemical Engineering, for the Bio-medical Engineering (BME) part of the Course. If the first degree requires more than four years to undergraduate University studies, then the student of the fifth or higher year is also eligible as a candidate, provided that he/she has completed all his/her obligations of the first four years.

Prior to their departure for Patras, the students are notified of their admission and they receive the necessary travel, financial and accommodation information from their local coordinator.

Upon their arrival at the University of Patras, most of the Course students are accommodated in a Students House. Each student is offered a room and three meals per day for about 120 ECU per month. Private apartments are also available for rent, at monthly rates of 100 to 150 ECU. This way, the ERASMUS or TEMPUS student grant sufficiently covers all expenses.

The Course starts at the end of September and ends at the end of April. The first Semester consists of three monthly Modules. They are commonly addressed to engineers an physicists, because they include introductory Topics of interest to all of them. The Second Semester includes four monthly Modules. It consists of specific Topics for engineers and other Topics for physicists. They are given to these two groups in separate classrooms simultaneously.

The first weeks of each Module are devoted to teaching (four hourly lectures each and every working morning and laboratory practicals in most working afternoons).
The fourth week, is covered by written examinations on all of the Module's Topics. To reduce the number of examinations, two or three related Topics are joined in one Cluster, which is examined in one written test.

Finally, the student is given one grade for each Cluster, which is the weighed average of the grades of the Cluster Topics.

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At the end of his/her teaching period the teacher prepares the examination questions and gives them to the Course coordinator. At the examination day, the questions for each cluster are photocopied and distributed to the students, who have to answer them within two hours. The answers are photocopies and mailed to the teacher to be evaluated. The teacher mails the grades back to Patras.

During Christmas and Easter Holidays the Course in interrupted for two weeks each time.
The student who failed in up to 30% of the clusters, is given the opportunity of a second written examination on these clusters, during the month of May.

Finally, each student is awarded a certificate, which presents his/her attendance and success in passing the Clusters. The University of origin is already committed to recognising the Clusters passed and to give the corresponding credit to the student.

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MEDICAL PHYSICS IN HUNGARY

P. ZARAND[(1)]

STATUS

The population of Hungary is some 10.3 million and is slowly decreasing. The approximate number of beds in hospitals is 100,000 from these 500 beds are parts of the oncology centres, but the activity is shared in some centres between radiotherapy and chemotherapy.

We have 10 radiotherapy centres (+2 under construction) which seems to be in accordance with the WHO recommendations. The location and the instrumentation of these centres are, however, far from optimal: five (from the 12) are just on or very near to the border, other 3 in East Hungary are lying on a triangle with 60km sides, only 4 of them have accelerator(s) although 9 of them have rooms planned for accelerators. These centres have a medical physics laboratories. Research institutes like the National Research Institute for Radiobiology and Radiohygiene, or the Central Research Institute for Physics (Radiation Protection Department), the Nuclear Power Plant at Paks (Radiation Protection Departments) and the National Office for Metrology (Primary Calibration Laboratory) have laboratories and groups working in related topics. A few radiation protection laboratories are working as part of the radiation protection network of the authorities.

About 30 medical physicists (a few places are vacant) are employed in hospitals mainly in radiation therapy departments usually with more than 5 years experience and different education depending mainly on local equipment and instrumentation. This results in 2.5 physicists/million inhabitants being in the lower half in Europe. The number of physicists/centres varies between 1 and 7. Radiation protection is usually a part time job (with no salary) of the medical physicist(s) and its level is highly dependent on both the local requirements and the engagement of the physicists. The number of medical physicists working in the radiation protection network of the authorities is 7-8. The number of medical physicist working in nuclear medicine is approximately 17-18. The non-doctors in this field usually have, at least in our country, education in physics, electrical engineering, chemistry, pharmacy or biology.

At present there is no legislation regulating the number and qualification of "medical physicists". In the early era of megavoltage therapy e.g. in the "grey book" 1/2 (later 1) physicist per therapy unit per shift was recommended and then 1 physicist per centre was added for computer aided treatment planing in

1978. The workload of a centre has not been considered. It is varying between 500 and 3000 new patients per year. Since approximately '86 neither a valid recommendation nor legislation exist and a manpower figure close to that suggested by EFOMP (1991) is accepted in practice.

REPRESENTING BODY

Medical physicists in Hungary working in radiotherapy or diagnostic radiology are organised in the "Medical Physics Section of the Hungarian Biophysics Society" (this section is a member of both IOMP and EFOMP) and about half of them have some kind of radiation protection responsibilities and are also members of the Radiation Protection Section of the Roland Eotvos Physical Society. The physicists working in nuclear medicine departments are usually members of the appropriate Hungarian society.

EDUCATION AND TRAINING

The present low number of medical physicists is connected with the general problems in health care. Without discussing the reasons, it should be mentioned that the total number of "deep therapy" field/year has remained a constant 600.000 in the past 25 years. The cancer mortality is about 32.000 per year. from this figure 20.000 external therapy patients per year is expected (including recurrence). Using 20 fields per course and 2.5 fields per session a rough estimate of 1 million fields are needed. The actual number is approximately only half of it. Combining the WHO report 644 (new patients per equipment) and EFOMP staffing data then 50 medical physicists are required in the whole country. Similar data may be valid for nuclear medicine and radiation protection.

This results in practically two new physicists per topic per year and a formal graduate training in medical physics seems not to be feasible. Post graduate teaching course at one university, starting every 2-3 years can be an adequate solution. The curriculum of the medical physicist should harmonise with that accepted in the UK or Germany or preferably with that to be adopted by the EC. A good solution can be a training on a regional basis in English or German.

There are no university courses in Hungary where medical physicists can be educated to post-graduate level. Until now the Technical University (Budapest) has organised some post graduate courses in biomedical engineering supported by UNIDO. From the beginning of 1995 they are offering an accredited M.Sc programme containing 1080 hours plus thesis. This is organised in co operation with the Medical and Veterinary Universities of Budapest. Some parts of this programme (anatomy, physiology, statistics, etc.) can be very useful in the education of medical physicists. Radiation protection courses are organised at various levels. Two offered by Technical University can be useful for medical physicists: 50 hours theory + 65 hours practise for all medical physicists, while a special course is dealing with the planning of new installations (64 hours theory + 24 hours practise). Regular three day Training workshops are organised by our society in co operation with the Roentgen and Radiation Physics and The Clinical Science Foundation (CSF, London). This year our first annual conference, supported by the European Comunity and the CSF was held.

The special literature is not available in Hungarian . Since there is no organised education for medical physics in the country most of the books and periodicals are available only in research institutes where the main profile of the activity is quite different. Recently the Medical Physics Section of the Hungarian Biophysics Society has received some 50 books on different topics of medical physics and some volumes of Health Physics from EFOMP. Since Hungarian is not the most commonly used language in the world the only possibility to get professional information is to have a good knowledge of English.

In Hungary a certificate of specialisation cannot be given by a medical society. This has no tradition at all in medicine, consequently a possible certification by another society is not recognised. For medical doctors a special office, the Committee on Medical Specialisation is responsible for certification in a speciality. This body is not responsible for the post graduate education of any people not having the education from a medical university.

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POST-GRADUATE EDUCATION IN MEDICAL RADIATION PHYSICS IN THE REPUBLIC OF IRELAND

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INTRODUCTION

Internationally accepted routes for post-graduate education in the field of medical radiation physics include taught Master's degree courses, Master's and Doctorate degrees by research alone, and courses managed by the various professional organisations. These formal educational options need to be supplemented by in-service training, as well as continuing education opportunities. Most of these educational options are available to medical physicists in the Republic of Ireland, with the exception that the professional body, the Association of Physical Scientists in Medicine (APSM), does not manage its own training course, but was instrumental in setting up a taught Master's degree course which is now managed by Trinity College, Dublin University (TCD).

With regard to undergraduate education, some courses include a medical physics or physiological measurement component. Diploma-level education, as well as professional education for technicians in this field have not been adequately developed as yet. The TCD post-graduate course is the only structured educational option dedicated wholly to the application of physical sciences to medicine which is presently available in Ireland, and the remainder of this paper will deal mainly with the TCD course.

GENERAL PERSPECTIVES

The Physical Science in Medicine course offered by TCD integrates medical radiation physics with the broader field of physical science applications in medicine (e.g. physiological measurement, rehabilitation engineering). This broad-curriculum approach is suited to the present health services structure in Ireland, which supports relatively small, hospital-based medical physics departments; in such departments narrow specialisation is not normally feasible and physicists must expect to contribute to a broad range of demands, such as electromedical equipment management, physiological measurement, quality assurance and rehabilitation engineering as well as the traditional radiation physics and imaging services. The integrative approach is not peculair to the Irish context. The accreditation scheme introduced by the Institute of Physical Sciences in Medicine (IPSM) encourages a broad-based curriculum, and many benefits for this can be cited such as: fostering closer cohesion among the various branches of the profession; crossover of knowledge from different fields; avoidance of the prohibitive costs of running a number of separate courses for relatively small numbers of students.

Students of the Physical Sciences in Medicine course at TCD may register for either an MSc or Diploma. The registration requirements (good honours degree in the Physical Sciences), curriculum and examination procedures for the taught section of the Masters and Diploma courses are identical. The course is timetabled so as to accommodate students who are in full-time employment in the field of physical sciences in medicine, and runs over a two-year duration.

In addition, to passing all the set examinations for the taught course, Master's degree students must submit a dissertation which demonstrates the ability to define, research and report a significant piece of scientific work in the field of physical sciences in medicine. Thus the Master's degree certifies that the student has all the knowledge and skills necessary to a new entrant to the profession of physical sciences in medicine.

The option of registering for a Diploma is useful for students from fields outside of the Physical Sciences in Medicine Profession (e.g. hospital management or medical industry); it is also attractive to those wishing to enter the profession but who do not feel the need to demonstrate research skills, e.g. to students who may have already obtained an MSc or PhD by research alone.

STATUS

The status of Trinity College, Dublin University is well recognised, so that the Master's degree and the Diploma enjoy excellent status both nationally and internationally. Inaddition the MSc course enjoys full accredation from the Institute of Physical Sciences in Medicine (IPSM), and was among the small number of courses to achieve this status in the first year of the accredation scheme.

NEEDS

At present there are less than 50 graduate posts in Medical Physics/Clinical Engineering in the Irish Republic. This figure signifies a considerable under-staffing problem. In order to provide an effective scientific support for health services in the country at least 100 new graduate posts must be created. It is difficult to forecast the rate of creation of new posts, but despite the financial problems of the Irish Health Services, it is reasonable to estimate that at least 4-

5 jobs per annum will be created over the next few years, and that there will be some additional vacancies due to natural turn-over. Thus the training services are required to educate approximately 5 graduates per year in the field of Physical Sciences in Medicine. A self-financing course can be run with this level of intake, but the fees from just 5 students per annum do not provide sufficient finance to operate more than one course. Despite the fact that a sound financial case can be made for the course, and the evident need for a formal education course in Ireland, the TCD course costs have not yet been formally underwritten by either the University or any other body such as the Department of Health; thus the financial basis of the course is at present insecure.

SYLLABUS

The Physical Sciences in Medicine taught course has four major branches:

(i) Imaging Science and Technology (including diagnostic radiology, nuclear medicine as well as non-ionising imaging modalities and image processing);
(ii) Physiological Measurement (including electronic instrumentation design and signal processing);
(iii) Safety (including ionizing radiation safety, electrical, mechanical, chemical, fire safety etc as well as safety legislation);
(iv) Therapeutic Instrumentation (including radiotherapy, rehabilitation engineering and electromedical therapeutic instrumentation).

The syllabus is taught in the form of lectures (about 230 hours total) as well as demonstrations/hospital visits (about 80 hours total). Formal examinations are held each year (six examinations over the two-year period), and these are monitored by the MSc Course Committee and an External Examiner. Students must sit examinations in all subjects i.e. students may not specialise in a particular area such as medical radiation physics, and
are expected to achieve a good understanding of the overall field.

RESEARCH COMPONENT

The ability to conduct independent research is essential to the role of the medical physicist: research projects stimulate critical review of practise, safeguard against out-dated practises, provide a mechanism for contact with assessment and development of research skills, Master's students are required to undertake a supervised research project in the field of physical sciences in medicine. The project must address a worthwhile scientific (or occasionally a professional) problem, and examples of some recent dissertations include:

The Resolving Power of Flexible Endoscopes
Blood Pressure Simulation in a Tubular Model;
Bone Mineral Measurement using Digital Fluoroscopy and Computer Radiography;

Stimulation of Gustatory Brain Potentials;
Qauntitive Analysis of Noise in Hospitals;
Uniformity Analysis in X-ray Image Intensifier/TV Systems;
Digital Image Restoration Techniques applied for Nuclear Medicine and Radioaerosol Imaging.

The dissertation must demonstrate that the student is capable of carrying out and reporting the research project to professionally acceptable standards (i.e. standards that would be considered acceptable to a good quality peer-review journal).

IN-SERVICE TRAINING

Students who are not in full-time employment in the field of physical sciences in medicine are expected to complete a twelve-week placement at a hospital or other institution in order to gain some insight to the practice of the profession in Ireland. However no formal training posts have been established as of yet, so that students do not gain practical experience of all the various specialities within the ambit of Physical Sciences in Medicine. To date, informal rotation practices have allowed many students to gain experience in fields other than radiotherapy, but the absence of a formal, co-ordinated rotation scheme has led to the current serious shortfall of experienced radiotherapy physicists in Ireland. Thus, despite the fact that practice in many fields of medical physics is recognised to be excellent (e.g. students have travelled from other European countries to obtain experience in Irish hospitals) the in-service training component is not well developed in Ireland and is not assessed formally. This problem is presently being addressed by the professional body.

CONTINUING EDUCATION

The provision of continuing education in Ireland is complicated by the small size of the Medical Physics community here at present, and the high costs of attending meetings overseas. Despite this, lectures, workshops and scientific meetings are held on a regular basis by a number of professional associations, and Irish delegates often attend and contribute to international conferences. Many Irish hospitals enjoy close association with third-level educational establishments, and thus medical physicists usually have good access to the published literature, and often contribute to this literature.

SUMMARY

While there are a number of significant gaps in the development of professional education in the field of Physical Science in Medicine in Ireland (including the absence of structured in-service graduate training and technician training) the graduate taught program at TCD provides an appreciation of the academic and practical core of knowledge in this field.

The syllabus includes subjects such as physiological measurement as well as the subjects traditionally taught in courses in medical radiation physics. The program enjoys university status as well as accreditation from IPSM, and is recognised as providing the knowledge and skills necessary for new entrants to the profession.

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CURRENT STATUS OF MEDICAL PHYSICS IN ITALY

F. MILANO[(1)]

ORGANISATION OF HEALTH PHYSICS SERVICE

Health Physics Services in hospitals in Italy, were established by law in 1969 (D.P.R. 27.3.69 N. 130 art 34) with the aim of giving a contribution "to solve problems related with the use of ionizing radiation and in electronic application in medicine". Before that time, since the early sixties, some physicists however worked in radiotherapy departments.

In order to have access to the initial position in the Health Physics Services the applicant has to pass a mandatory public exam for the planned position with the only prerequisite of having a university degree in Physics. The positions are divided into three levels. The passage from one level to another is based on a public exam after a four year experience in the previous level and an eight year experience, respectively from the first to the second and from the second to the third level.

The regulation changed last year, even though it has not yet been applied. The new organisation of staff will only be on two levels. In order to enter the first level applicants must have a degree in Physics and a post-graduate degree in Health Physics.

NUMBER OF PHYSICISTS, SERVICE DISTRIBUTION IN THE COUNTRY AND THEIR ACTIVITY

The number of physicists in the Health Physics Services inside the National Health Service (NHS) is about 5 per million inhabitants. The Italian population is about 57 millions. In 1993 300 hospital physicists operated in 95 services, 34 independent and 61 aggregated to medical specialities like radiotherapy, radiology and nuclear medicine. (1). The number of physicists in the single service depends on the activities which are performed, the area of competence of the service, the amount and the complexity of equipment. 80% of the total number of physicists are placed in services in the northern part of Italy.

In the National Health Service some physicists are also employed in environmental and prevention areas. Sometimes their activity covers elements of medical physics.

Another important area of medical physics activity is in the universities and research institutes.

In the following table an estimate is reported for the physicists involved in the area of medical physics.

ESTIMATE OF THE NUMBER OF MEDICAL PHYSICISTS IN ITALY

Number of Physicists	Number of Service Sections	Type
300	95	Hospitals
120	60	Environmental
250	30	University and Research Institute
670	185	Total

HEALTH PHYSICS SERVICE ACTIVITY IN THE NHS

Radiotherapy	21.4%
Nuclear Medicine	23%
Statistics	12.8%
Informatics	11.1%
Quality Control	19.7%
Research	12%

ENVIRONMENTAL SERVICE ACTIVITY IN THE NHS

Acoustic pollution	26.7%
Atmospheric pollution	20%
Microclimate	11.1%
Ionizing Radiation	28.9%
Non-ionizing Radiation	13.3%

No investigation has been made about the number of engineers involved in the medical specialities. A rough estimate of their number is about 10% of the physicists.

The prominent kind of activity carried out inside the National Health Service in 1988 is reported in the following tables. Radiation protection is not included in the tables even if many physicists of the NHS are involved in this activity.

REPRESENTATIVE BODY

In 1987 the "Associazione Italiana di Fisica Biomedica" (AIFB) was founded with the aim of promoting the activity of research and to provide educational and professional training in medical physics. The association joins the major part of medical physicists in every field of activity. Actually the Society has about 400 members.

The Society issues "Physica Medica" an International journal, which is the official journal of AIFB (Associazone Italiana di Fisica Medica), DGMP (Deutsche Gessellschaft fur Medizinesche Physik) and NVFK (Nederlandse Verening voor Klinische Fysika). Physica Medica is now indexed/abstracted in EMBASE (Excerpta Medica Data Base), INSPEC (for Current Papers in Physics and Physics Abstracts), QUEST (a data base dedicated to Health Physics and Medical Physics Journals) and ISI (for Biophysics and Biochemistry Citation Index).

The "Societa Italiana di Fisica" (SIF) is another representative body that joins all physicists in Italy. SIF has, in its yearly National congress, a section dedicated to Medical Physics and Biophysics. Some physicists acting in medical physics are members of SIF and very often they have inscription to both Societies.

GENERAL EDUCATION OF A MEDICAL PHYSICIST

The educational entry requirement of a medical physicist is the university degree in physics. The degree is obtained after a four year course and corresponds to a masters degree. In these studies courses that in some foreign curricula are considered graduate courses, are introduced. After the degree it is possible to attend Ph.D training. A rough estimate in 1991 indicates that there are less than 4000 Ph.D positions for 80000 applicants from all university disciplines.

Recently a three-year university diploma has been introduced which however is not active for physics.

The preparation of a physicist in Italy, is at a higher level than the B.Sc. level but it does not give any specific preparation in medical physics. Only since last year it is possible to have some specific courses, 5 in number, in the physics curriculum, the so-called Physics of Biosystems, area related to items of medical physics.

POST GRADUATE EDUCATION

The only specific training in medical physics is given by the post-graduate School of Specialization of the University.

In 1994 there are post graduate Schools at the Universities of Milan (15 positions per year) Bologna, (15 positions), Florence (5 positions), Pisa (5 positions), Rome La Sapienza and Rome Tor Vergata (15 positions). The education level for access to the school is a degree in Physics, Chemistry, Industrial Chemistry and Engineering. The duration of the school is two years, excepting one school in Rome which is three years.

The courses are programmed in lectures and practical training. The total number of hours is 400 hours per year for formal and practical training, seminars and visits to outside institutions and laboratories.
The academic programme contains a set of topics as follows:-

Selected topics in Physics
Elements of anatomy, biology, and physiology
Radiation physics and dosimetry
Biomedical instrumentation and techniques
Non-ionizing radiations
Radiation protection of staff
Environmental radiation measurements
Informatics
Statistics
Regulations

The course contents may differ from one university to another.

In future the general agreement is to request the transformation of the existing two year schools into four year schools with grants to students enrolled, following the EC model. The entry requirements will only be a degree in Physics.

FUTURE NEED OF MEDICAL PHYSICISTS

The number of physicists which operates in clinical structures is about 14 per million inhabitants in Sweden, 10 per million in the US and this evidence can induce an increase of their number in Italy. Actually there are 93 public radiotherapy centres in Italy (2) using 72 linacs, 46 with electron beams, 83 Cobalt 60 units, 6 cesium units and 112 x-ray units. There are 51 simulators. In 27 centres interstitial and in 49 endocavitary brachytherapy is active. The ratio number of Radiotherapy Centre per number of inhabitants (centre/number of inhabitants) in Italy is 1/614000 (1/594000 in the Middle Italy; 1/999000 in South Italy; 1/483000 in North Italy). Considering an optimal ratio of 1/500000, there is the need of other 15-20 Radiotherapy centres. 4 Italian Regions have no Radiotherapy centres. Their population is about 3.18 millions of inhabitants.

The number of public Nuclear Medicine Services is 154 (3). Moreover public opinion is very sensitive to pollution and, as previously exposed, in this area physicist competence is required. These facts indicate a tendency of the increasing physicists in number. On the other hand the course containment programs and some changes in the organization of the National Health Service, which are presently in course, do not permit prediction of real future trends.

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POST-GRADUATE EDUCATION IN MEDICAL RADIATION PHYSICS AND BIOPHYSICS IN LATVIA

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STATUS

Latvia has no nuclear power plants and radiation fuel processing. Thus, medicine, agriculture, industry and science are the main branches where radiation is used in the Republic of Latvia. Medicine has radioisotope sources, radio pharmaceutical preparations (eight hospitals and oncology clinics). ^{222}Rn is applied for physiotherapy by eight hospitals and sanatoriums, in addition. Besides, X-ray equipment is installed in about 250 hospitals. Up to of 50 agriculture establishments use radioisotope sources, mainly in the relay-type equipment. Gamma - radiography and various radioisotope instruments are found in 200 industrial enterprises. Science applies radiation (as radioactive substances, nuclear reactor and electron accelerator) is used in about 20 research groups. Transportation of radioactive materials for users is supplied by the special company "Radon" and the Department of Health. Specialised vehicles are being used for this purpose. The medical aspect of radiation physics consists of dosimetry for personal monitoring, treatment and investigation of process which are carried out in biological systems. For providing these directions thermoluminescent dosimetry systems and semiconductor detectors have been developed. Different scientific searches touch on the exerting of radiation influence on biological objects. The main results of these are as follows: tissue - equivalent phantoms, evaluation methods of radiation risk have been created.

The activity of the mentioned branches is being regulated by the Latvian legislation according to the requirements of such International Organisations as the Commission of Radiation Protection the International Atomic Energy Agency, the Commission of European Community, etc.

EDUCATION, RESEARCH AND FUTURE NEEDS

An adequate education is necessary to realise radiation application principles. The studying process is organised mainly at Latvian University, Medicine Academy and Riga Technical University.

Latvian University has 20 years experience in the education of specialists in radiochemistry, radiation chemistry, radioncology and applied dosimetry. Bachelors' and Masters' degrees are received by graduated students. Following special courses are attended : radiation chemistry, radioecology, radiation and environment, radiation checking of food, nuclear physics and dosimetry, dosimetry. Special equipment is being used to provide education : radiation sources dosimeters radiometers, ionization and scintillation counters. Alpha, gamma, beta, neutron irradiations are available too, in particular due to collaboration with the National Centre of nuclear Investigations. Doctorants for the above directions are trained too. The main problem of the education process development are lack of modern equipment and means for acquisition of expensive radiation sources. Medical Academy provides mainly the education of physicians as radiologists. Riga Technical University develops two main ways related to radiation physics. Courses for education of technician dosimetrists have been organised. New speciality Medical Engineering and Physics has been established. This has been made in frameworks of the scientific and training direction of Applied Physics. Development of Medical Engineering and Physics speciality is foreseen using International Co- Operation.

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Medical Radiation Physics

MEDICAL PHYSICS IN LITHUANIA

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STATUS

Lithuania is a small country in the Southeast of the Baltic States. The population of Lithuania is approximately 3.7 million. There are 44 districts in Lithuania. Potentials of culture and science are concentrated in the 5 biggest cities. The capital of Lithuania is Vilnius.

The medical physics and engineering departments and laboratories are concentrated in Vilnius and Kaunas in the following departments:

-Laboratory of Clinical Dosimetry and Radiobiology in Lithuanian Oncology Centre, Vilnius (Radiotherapy).
-Department of Radiology of Kaunas Medical Academy Hospital, Kaunas (Radiotherapy).
-Department of Medical Engineering, Kaunas Medical Academy Hospital, Kaunas (Service Engineers).
-Laboratory of Dosimetry, Vilnius University, Centre of Radiology, Vilnius.
-Laboratory of Imaging, Kaunas University, centre of Radiology, Vilnius:
-Radiological Laboratory, National Centre of Hygiene, Vilnius:
-Five Regional Radiological Laboratories of Radiation Hygiene and Imaging.

The approximate number of medical physicists and engineers is about 40. They are involved in Radiotherapy (12), Diagnostic Radiology (3-4), Nuclear Medicine (11), Radiation Safety (11), Radiation Hygiene and Imaging (4-5). The approximate number if service engineers, working in Diagnostic Radiology is about 50-60.

REPRESENTATIVE BODY

Medical Physicists of Lithuania are represented by the Lithuanian Association of Radiologists and by the Committee of Clinical Dosimetry, Radiation Hygiene, Radiobiology and Radiation Engineering of this Association.

EDUCATION

Undergraduate studies of radiation physics are not specifically orientated to medical radiation physics either at Vilnius University or at Kaunas University of Technology. There are no facilities or institutions in Lithuania for the education of medical physicists or training in radiotherapy. All the medical physicists working in Lithuania have been trained abroad, the majority in the former USSR.

The specialists for Radiation Safety are trained in radiation hygiene at the Vilnius University - 1 year residence.

The specialists for Diagnostic Radiology and Nuclear Medicine undertake a course (3 years) on medical engineering at Vilnius Technical College (20 per year) or a course (4 years) on biomechanics at Vilnius Technical University (10 per year).

CONCLUSION

There are no unified programmes for education of medical radiation physicists in Lithuania. There is a great need for co-operation with other Universities and Institutions in the field of education and training.

International support is necessary for education of medical physicists and for training courses, research and studies for specialists working at present for shorter or longer time in the European centres.

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PROFESSIONAL TRAINING ON MEDICAL PHYSICS IN THE NETHERLANDS

P. INIA [(1)]

INTRODUCTION

Representing Body - NVKF

The Netherlands Society of Clinical Physics (Netherlandse Vereniging voor Klinische Fysica, NVKF) has got about 250 members. It represents nearly all clinical physicists working in the Netherlands in several areas of specialisation, such as audiology, general hospital instrumentation, medical informatics, nuclear medicine, therapeutic and diagnostic radiology. It has installed two committees for organising the post academic professional training for the clinical physicists. These committees are the Legislative Educational Committee (Council) and the Executive Educational Committee (Toetsingscommissie).

Aim of professional training

In the course f the professional trainee must acquire adequate knowledge and experience to be able to co-operate with medical and paramedical specialists and other health care workers to provide for the physical aspects of medical practice and for the safe and correct application of medical instrumentation. After completion of the training, the trainee should be able to function independently as a clinical physicist in his area of specialisation and to accept the associated responsibility towards the patient, the staff, the management of the Institute and public authorities, all of this in agreement with the professional rules for the clinical physicist.

General and special requirements

The Legislative Educational Committee frames requirements for the professional training according to clause 2a of its regulations. The requirements applicable to all areas of specialisation are described in the document "General requirements for professional training". Requirements that can differ for each area of specialisation are given in other document - "Special requirements for professional training".

Executive Educational Committee

The Executive Education Committee has to verify that in individual cases these requirements are met. It is important to note that the regulations of this committee give it the right to deviate from the general and the special requirements, for instance if a trainee possesses previous relevant knowledge or experience.

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GENERAL REQUIREMENTS FOR PROFESSIONAL TRAINING

1.1 Entry qualifications for entrance

1.1.1. To be admitted to the professional training a trainee should possess a master's or a doctor's degree in physics from a university in the Netherlands, o r a degree that is considered of equal merit by the Executive Educational Committee.

1.1.2. The trainee should be employed by a qualified institute for at least 50% of a full-time job and be under the guidance of a qualified mentor.

1.2. Duration of Training

1.2.1. The duration of the training is based on a schedule equivalent to a minimum of 3 years and a maximum of 4 years full time, during which time the trainee must be employed by the training institute.

1.2.2. The duration of the training in a particular area of specialisation is stated in the "Special requirements for professional training".

1.3. Areas of Specialisation

The professional training is divided into several areas of specialisation.

1.4. Level of professional training

A large number of topics should be studied, including anatomy, physiology, pathology, mathematics, statistics, physics, electronics, computer science, business economics, management and organisation of health care. Part of the knowledge to be acquired, that is of a general nature, is needed for a good understanding of medical practice. The other more specialised part of the knowledge is meant to be applied directly and to enable the clinical physicist to bear final responsibility for certain matters.

A general indication of the level of professional training can be deducted from the required previous academic training and the aim of the training programme.

1.5. Training programme

1.5.1. Set up of a training programme:
The training programme consisting of a list of topics to be studied and tasks to be performed, is composed by the mentor in accordance with the

lists of topics in the "Special requirements for professional training" of the area of specialisation concerned (see clause 1.5.3).

1.5.2. Mandatory components of the training programme:

Every programme includes the following:

- Participation in relevant training courses
- Regular participation in relevant local or regional meetings about clinical subjects
- Regular participation in local, regional, national and possibly international scientific meetings.
- Participation in local, regional or national working groups
- Participation in applied clinical research that yields at least one scientific publication and one presentation at a scientific meeting.
- Visits to other institutes
- Teaching to members of the staff of the institute

1.5.3 Topics and tasks:

For each are of specialisation "Special requirements for professional training" are set up. They provide lists with topics to be studied, tasks and literature,. These lists serve as a guideline for composing the training programme.

GENERAL REQUIREMENTS FOR ORGANISING PROFESSIONAL TRAINING

2.1 Requirements for the mentor

2.1.1. The mentor should have a full time job with the same training institute as the trainee.

2.1.2. When the training starts the mentor should have been employed for a least two years as a registered clinical physicist with the same area of specialisation as the trainee.

2.1.3. Requirements mentioned in clause 2.1.1 and 2.1.2 can be supplemented by the "Special requirements for professional training".

2.2. Requirements for the institute of professional training

2.2.1. The number and variety of examinations, treatments or consultations should be such that all relevant aspects can be dealt with sufficiently during the training period. If there is a close co-operation with one or more other departments or institutes of health care, this requirements is valid for those departments or institutes jointly.

2.2.2. Adequate instruments for examination and treatment of patients, for technical and physical measurements, and for calculations and data management should be available in sufficient number and variety.

2.2.3. Sufficient technical support (electronics, fine mechanics, technical service) should be available at adequate levels.

2.2.4. Sufficient staff and laboratory space should be available.

2.2.5. Documentation and archiving of results of investigations, examinations and treatments or consultations should be well organised.

2.2.6. Structured meetings should be held on a regular basis with co-operating medical, paramedical and other departments or institutes. This applies both to patient care and management.

2.2.7. The library should possess recent handbooks and journals in the field of specialisation.

2.2.8. Requirements mentioned in clause 2.2.1. up to 2.2.7. can be supplemented by the "Special requirements for professional training".

3. Revision

The General and Special requirements for professional training shall be subject to revision at least once every five years.

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EDUCATION IN MEDICAL RADIATION PHYSICS IN POLAND

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HISTORY

The tradition of medical radiation physics in Poland dates from the early thirties when M Sklodowska-Curie establishing the Radium Institute in Warsaw (with a large Physics Department) started a co-operation with the Physics Faculty of Warsaw University. This faculty was the main source of physics staff in the Radium Institute. After the Second World War until the mid-sixties medical physicists were graduated mainly from Warsaw Technical University where the program of specialisation in Technical Physics was adjusted to the needs of radiation physics by Prof. Pawlowski (assistant to M. Curie). Later on physicists from the Physics Faculties of Universities and Academies of Education came to work in hospitals where radiation physics was applied.

ACADEMIC EDUCATION

The first impetus to start education and training of medical physicists on a regular basis came from the IAEA/WHO Seminar in 1972. The report from that Seminar prepared for the Polish Academy of Sciences by Oskar Chomicki was widely circulated. It finally found a response at Warsaw University where in the same year the program of education was established as a specialization during the fourth and fifth years of experimental physics.

The program was a result of many discussions among various specialists both in Poland and the United Kingdom. Since that time medical physics was recognised as a specialisation and also the possibility of scientific careers was opened for medical physicists. Later on, in 1979, the Medical Physics specialisation was set up also at the University in Krakow. Although the Krakow program is concentrated more around biophysical subjects, the Warsaw program around radiation physics in radiodiagnostics and radiotherapy, analyses of biosignals and imaging, the common features of both programs is that they provide training in a wide spectrum of subjects.

Table I. Medical Physics Programme at the Warsaw University

Year of Study	Subject	Hours per year
IV	- Cell biology and physiology - Physical fundamentals of radiation diagnostics - Radiation dosimetry - Radiotherapy planning - Statistical methods in biology - Bioelectricity and biocybernetics - Medical physics laboratory - *Seminars	30 50 30 30 100 80 150 50
V	- Biochemistry - Mathematical modelling of processes in biology and medicine - *Seminars - MSc Thesis	30 50 50
VI	- *Seminars - MSc Thesis	50

* The subjects of seminars are devoted to the problems connected to medical and health physics as well as biophysics and bioengineering. The invited speakers are specialists in the field, some seminars are prepared by the students.

Table II. Examples of MSc theses in radiation physics. The theses were prepared at Warsaw University in co-operation with the Medical Physics Departments of Cancer Centre in Warsaw.

- Analysis and verification of various computer programs used in radiotherapy (1988)
- Calculation of dose distributions by means of Clarkson method - investigation of parameters (1988)
- Measurements of Modulation transfer Function in diagnostic radiology (1989)
- Experimental verification of Fermi-Eyges theory for electron scanning beam (1990)
- Analysis of Compton-scattering in scintigraphic pictures (1992)
- Density measurements in CT (1993)
- Accuracy of dose rate determination in the ICRU-reference point (1993)
- Contrast and resolution measurements in CT (1993)
- Measurement and evaluation of physical parameters in mammography (1994)

Poland, Warsaw

The specialisation in technical physics oriented towards medicine has been build up over the last years at some technical universities all over Poland. Starting from 1990 at the Academy of Mining and Metallurgy (AGH) in Krakow there are B.Sc. and M.Sc. courses in medical physics and dosimetry. Warsaw and Kracow established multi lateral co-operation with various biomedical institutions e.g. in teaching staff exchange, organising laboratory classes, providing M.Sc and Ph.D tutoring. The education at engineering universities is mainly based on their own possibilities and has a rather technical profile.

PROFESSIONAL AND SCIENTIFIC STATUS QUO

Nowadays about 200 medical radiation physicists and engineers, not including service engineers, work in various hospitals and institutes (the population of Poland is almost 40 million).

In **Table III** the number of radiotherapy units, diagnostic radiology equipment, nuclear medicine equipment and the approximate number of hospital physicists employed. As can bee seen the radiotherapy physicists are the most numerous group. They are employed either in regional Cancer Centres (CC) in special sections at Radiotherapy Departments or in separate Medical Physics Departments (MPD), which are oriented not only uniquely towards RT. In Figure I the structure of the largest MPD in Poland with 20 physicists employed is shown. In other MPDs related to radiotherapy the number of physicists is between 2 and 6. Radiotherapy is performed only in large government hospitals and the distribution of these hospitals is quite uniform all over Poland. In Nuclear Medicine Departments and Radiology Departments usually not more than one physicist is employed. There are Biophysics Departments in Academies of Medicine, but radiation physics is a marginal subject there. Radiation physicists are also involved in development and production of Polish made accelerators, simulators, dosimeters and detectors, and in production of isotopes. The main institution for dealing with radiation safety matters is the Central Laboratory for Radiological Protection with about 50 highly qualified physicists and engineers employed. The duties of radiation protection officer in most hospitals are usually performed as additional responsibility by one of the physicists from the staff. In some big institutions with numerous isotope laboratories and sources of ionizing radiation the safety surveillance requires a full time post.

Presently the MPD or sections in Polish hospitals are seriously understaffed. The number of medical physicists per patient in radiotherapy in Poland is about two times smaller than in West European countries. Due to low salaries and not very promising career opportunities in the profession many physicists switched from medical physics to other disciplines or simply left Poland in recent years.

Hospital Physicists deal mainly with routine duties in hospitals and participate in clinical projects. Only part of them are involved in research and educational activities. Research concentrates mainly on theoretical problems or practical implementations closely connected with the clinical needs. Only physicists from larger facilities or universities are in position to get Ph.D degrees. Some of these dissertations result from co-operation with better-equipped institutes abroad.

POST GRADUATE EDUCATION AND OTHER ACTIVITIES

Poland has neither legislation on certification procedures for medical radiation physicists nor national requirement for their postgraduate education. The only exception is radiation safety, where the certification procedure for radiation officers is satisfactory regulated.

Post-graduate training is done on individual basis. The entry requirement for such training is MSc in physics, the specialised under-graduate education in radiation physics is not obligatory. Thus the physicists, who starts his training is usually on the level I or II of EFOMP competency scale. The specialised training in clinical practice is done under supervision of more experienced colleagues. Some physicists undergo an individual training in other institutes and voluntarily attend courses and meetings.

Since the sixties until mid-eighties MPD of CC in Warsaw organized each year one-month training courses on radiation physics in radiotherapy and nuclear medicine. Presently the staff of MDP is very much involved in academic teaching so the courses are discontinued, however individual training of the physicists from other hospitals are still being held. The Warsaw courses were replaced by the three days meetings on radiation physics in radiotherapy for physicians and physicists in Bydgoszcz. The main goal of the meetings is specialised education but different forms of active participation are welcome: presentations and posters on interesting developments in hospitals, discussions on "homework" which has to be prepared by participants.

In 1993 the Second International Summer School "Physics in Radiotherapy" took place in Warsaw (the first one was in 1977). Well known physicists from Western Europe and the United States presented excellent lectures on up to date topics in radiation physics. 70 participants came from Central and East

European Countries including 20 from Poland. The Schools (at advanced level) are intended to be organised every third year in framework of European School of Oncology (ESO), the Third School is planned for 1996.

Some Polish physicists attended the international courses (ESTRO, IAEA) and some of them underwent professional training abroad in a framework of international bilateral programs in medicine in Belgium, France, the Netherlands, Sweden, UK, USA.

Every fourth year the general meetings of members of Polish Society of Medical Physicists (PTFM) take place. One of them (international) was devoted to educational problems. PTFM (established in 1966) has about 300 members (about 60% of them are hospital physicists). PTFM works in following sections: 1) medical radiophysics 2) bioengineering 3) radiation safety 4) biophysics The president of the Society is Prof. G. Pawlicki (both physician and engineer). Meetings of sections are organised at least once a year.

The Medical Physics Section of the Polish Academy of Sciences brings together senior professionals interested in medical physics problems and organises their meetings once or twice a year.

For more than twenty years a national journal devoted to progress in medical physics has been issued as the PTFM journal (Postepy Fizyki Medycznej). Significant contribution to the publications has been given by radiation physicists. The physicists have also possibilities to publish in a few Polish medical journals. The Polish literature on medical radiation physics is rather limited. The basic literature is mainly in English and is seldom available in smaller centres.

Table 3. Approx. number of radiation hospital equipment and physicists

Department	**Equipment**	**No. Units**	**No. Physicists**
Radiotherapy	Cobalt Unit	28	total
(17 Depart's)	Accelerator	23	80
	Afterloading sys.	22	
Nuclear Med.	Scint.cam.&scanners	60	30
Diagnostic	X-ray equip.(ex.dent.)	4000	
Radiology	Mammographs	150	total
	CT scanner	100	10
	MRI	8	

Medical Radiation Physics

CONCLUSIONS

Introduction of a national post-graduate education and training programme with certification procedure for Polish medical physicists is an urgent matter for the near future. However, the establishment of such programs might be a long-term process: it will require a lot of efforts from the physicists themselves and from some authorities like Ministry of Health and Ministry of Education. It would also require serious financial resources. The certification procedure should be followed by better financial prospects for clinical physicists.

The role of pan-European collaboration in the strengthening of national activities in this field should be emphasised here. The following activities can provide the starting point for such working relationship:

Directives of the Commission of the European Communities relating to basic safety standards and radiation protection of the patient;

EFOMP guidelines and EFOMP policy statements;

experiences of the countries with established training programme;

outcome of the first East\West European Conference on Medical Physics/Engineering Education.

Joint research projects on the Ph.D level between different Eastern and well equipped Western institutes would be beneficial for research activities of medical physicists. Significant financial support for such initiatives is absolutely essential.

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THE CURRICULUM OF MEDICAL PHYSICS IN KRAKÓW

M. WASILEWSKA-RADWANSKA(1) and M. P.R. WALIGORSKI(2,3)

INTRODUCTION

Brief History of Undergraduate Education (M.Sc.- level) in Medical Physics in Poland:

c.1950 - Technical Physics specialisation established:
*at the Warsaw Technical University, by Prof. Cezary PAWLOWSKI
*at the University of Mining and Metallurgy in Kraków, by Prof. Marian MI SOWICZ

1974 - Medical Physics programme initiated at Warsaw University by Prof. Ewa SKRZYPCZAK and Prof. Jerzy PNIEWSKI, as a specialisation over the fourth and fifth years of the undergraduate course in Experimental Physics

1979 - Medical Physics programme initiated at the Jagiellonian University (Krakow) by Prof. Andrzej HRYNKIEWICZ as a specialisation over the fourth and fifth years of the undergraduate course in Experimental Physics

1990 - Medical Physics and Dosimetry programme established at the University of Mining and Metallurgy by Prof. Jerzy NIEWODNICZANSKI (now led by Assoc. Prof Marta WASILEWSKA-RADWANSKA), in close cooperation with the Collegium Medicum of the Jagiellonian University (Prof. Zbigniew CHLAP, Prof. Zbigniew SZYBINSKI and Prof. Stanislaw KONTUREK). This specialisation began as an M.Sc Course (five years) in Applied Physics. Now (1994/95) two courses are offered: B.Sc level (1/2/3 years) and M.Sc-level (1 1/2 years)

Graduate Education (Ph.D-level) in Medical Physics in Poland:

PhD degrees in Medical Physics (strictly: Experimental Nuclear Physics) have been conferred by:

Warsaw University
Warsaw Technical University

Medical Radiation Physics

Jagiellonian University, Krakow
University of Mining and Metallurgy, Krakow
Institute of Nuclear Physics, Krakow
Institute of Atomic Energy, Otwock-Swierk (Warsaw)

Professional Training:

1977 - First Summer School on Physics in Radiotherapy, organised by the Medical Physics Department of the Cancer Centre in Warsaw.

1993 - Second International Summer School on physics in Radiotherapy, organized by Prof. Andrzej HLINIAK, Assoc. Prof. Barbara GWIAZDOWSKA and Oskar A CHOMICKI.

MEDICAL PHYSICS PROGRAMMES IN KRAKOW

The curricula consist of lectures, problem classes, laboratory classes and seminars.

* Jagiellonian University - Medical Physics and Environmental Protection Programme
* University of Mining and Metallurgy - Medical Physics and Dosimetry Programme

The following professional training is included in the Medical Physics and Dosimetry programme:

- "in vitro" laboratory techniques, after the fourth semester (4 weeks)
- "in vivo" clinical techniques, after the sixth semester (4 weeks)
- Diploma (M.Sc) training after the eighth semester.

Cooperation in teaching Medical Physics and Dosimetry courses.

- Collegium Medicum (University School of Medicine), Jagiellonian University,
- Institute of Molecular Biology, Jagiellonian University,
- Cancer Centre, Krakow Division
- Institute of Nuclear Physics Krakow
- Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Warsaw.

Since 1993 a regular Regional Seminar in Medical Physics and Dosimetry has been held at the University of Mining and Metallurgy, with invited lectures every two weeks, given by eminent specialists in medicine, experimental physics, medical physics, bioengineering and related subjects. The Seminar, intended for scientists, secondary-school teachers, students, and secondary school pupils, is also part of the activities of the Krakow Division of the Polish Medical Physics Society.

CAREER OPPORTUNITIES

Students seek employment in their own places, but the University assists them by maintaining contacts with research institutions, clinics, companies, etc and by arranging job interviews. The course structure is designed to prepare students for work in hospitals, health institutions, environmental monitoring, development laboratories and for research in biomedical engineering.

Research-oriented graduates can enter post-graduate Ph.D courses at the University of Mining and Metallurgy or at other collaborating institutions.

NEEDS FOR THE FUTURE

The programme at the University of Mining and Metallurgy in Krakow is a relatively new one, however apparently a very attractive one to our students. So far, many of the course subjects are being taught outside the Department of Physics and Nuclear Techniques of the Academy of Mining and Metallurgy. On the one hand this is advantageous to our students, on the other we observe some repetition and a certain lack of co-ordination between our different lecturers. We would like to develop a strong and advanced biomedical physics programme of education and research in our Department and elsewhere, incorporating the latest developments in detectors, imaging and accelerators for medical applications. As a community, we have considerable expertise in experimental and theoretical nuclear and solid state physics in Krakow on which to base a wide range of biomedical methods and techniques, hopefully arriving at a community of physicists, engineers and clinicians forming one of the largest research and education centres in Poland.

We expect to establish close collaboration with other teaching and research organisations in Europe, such as the Department of Medical Engineering and Physics of the King's College London, UK, Institute of Physical Sciences in

Medicine, European Federation of Organisations for Medical Physics, International Atomic Energy Agency, International Federation for Medical and Biological Engineering, European Scientific Institute.

We think that the European Conference on Post-Graduate Education in Medical Radiation Physics sponsored by the Commission of the European Communities under its activities for Co-Operation in Science and Technology with Central and Eastern is an extremely important step in bringing us all together.

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(2) Centre of Oncology, Kraków Division.
(3) Institute of Nuclear Physics.

Poland, Krakow

APPENDIX

UNIVERSITY OF MINING AND METALLURGY KRAKOW

MEDICAL PHYSICS AND DOSIMETRY PROGRAMME (ORIENTED SUBJECTS)

SUBJECT SEMESTER	1	2	3	4	5	6	7	8	9	10	NUMBER OF HOURS (TOTAL)
BIOMEDICAL SUBJECTS (ANATOMY, HISTOLOGY, PHYSIOLOGY, GENETICS, MOLECULAR BIOLOGY, CELL PATHOLOGY)		■		■	■	■	■				**225**
BIOCHEMISTRY			■	■							**60**
BIOPHYSICS AND BIOCYBERNETICS					■	■					**60**
RADIATION PHYSICS				■	■	■					**135**
DETECTORS OF NUCLEAR RADIATION					■						**75**
RADIOCHEMISTRY					■	■					**135**
RADIOPHARMACOLOGY						■					**45**
RADIOBIOLOGY						■	■	■			**60**
RADIOTHERAPY								■			**45**
NUCLEAR MEDICINE								■	■		**30**
DOSIMETRY						■	■	■			**180**
RADIATION PROTECTION							■				**45**
ELECTRONICS OF MEDICAL EQUIPMENT							■	■			**120**
BIOSTATISTICS								■			**45**
COMPUTER IMAGING				■	■						**150**
COMPUTER METHODS AND SYSTEMS IN MEDICINE							■	■			**45**
SEMINAR							■	■		■	**90**
M.Sc. THESIS									■	■	

Medical Radiation Physics

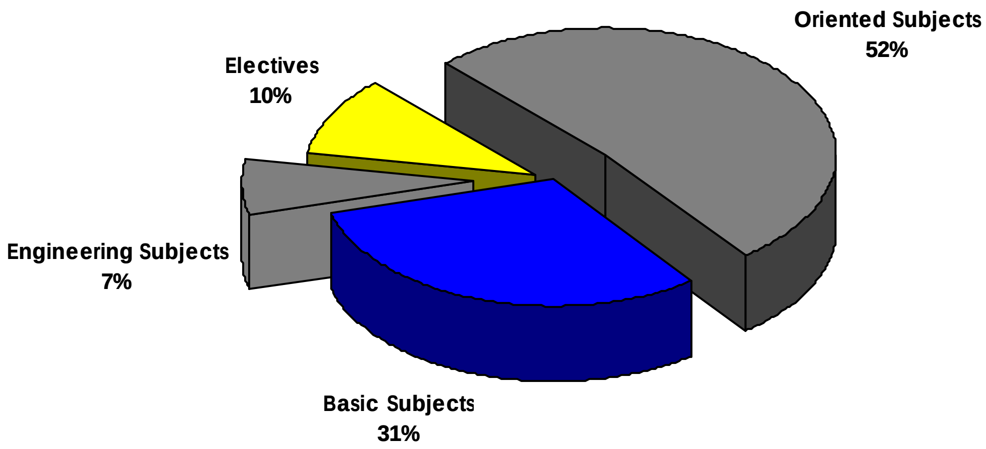
UNIVERSITY OF MINING AND METALLURGY KRAKOW

MEDICAL PHYSICS AND DOSIMETRY PROGRAMME

SUBJECT SEMESTER	1	2	3	4	5	6	7	8	9	10	NUMBER OF HOURS (TOTAL)
MATHEMATICS	■	■	■	■							**300**
INTRODUCTION TO STATISTICS	■										**45**
PHYSICS	■	■	■								**330**
COMPUTER SCIENCE		■	■								**150**
ELECTRONICS					■	■	■				**195**
CHEMISTRY	■										**90**
ELECTIVES							■	■	■	■	**300**

MEDICAL PHYSICS AND DOSIMETRY PROGRAMME

CONTRIBUTION OF TYPE OF SUBJECTS IN PROGRAMME



Poland, Krakow

UNIVERSITY OF MINING AND METALLURGY KRAKOW

MEDICAL PHYSICS AND DOSIMETRY
B. Sc. PROGRAMME

SUBJECT SEMESTER	1	2	3	4	5	6	7	NUMBER OF HOURS (TOTAL)
MATHEMATICS	■	■	■	■				**300**
INTRODUCTION TO STATISTICS	■							**45**
PHYSICS	■	■	■					**330**
COMPUTER SCIENCE		■	■					**150**
CHEMISTRY	■		■					**90**
ELECTRONICS				■	■	■		**195**
ELECTIVES							■	**120**

ORIENTED SUBJECTS

SUBJECT SEMESTER	**1**	**2**	**3**	**4**	**5**	**6**	**7**	NUMBER OF HOURS (TOTAL)
BIOMEDICAL SUBJECTS (ANATOMY, HISTOLOGY, PHYSIOLOGY, GENETICS, MOLECULAR BIOLOGY)		■		■	■	■		**225**
BIOCHEMISTRY			■	■				**60**
BIOPHYSIC & BIOCYBERNETICS					■	■		**60**
RADIATION PHYSICS				■	■			**135**
RADIOCHEMISTRY					■	■		**135**
RADIOPHARMACOLOGY						■		**30**
DOSIMETRY					■	■	■	**195**
RADIATION PROTECTION						■		**30**
ELECTRONICS OF MEDICAL EQUIPMENT							■	**60**
COMPUTER IMAGING				■	■			**120**
COMPUTER METHODS AND SYSTEMS IN MEDICINE							■	**60**
SEMINAR							■	**60**

UNIVERSITY OF MINING AND METALLURGY KRAKOW

MEDICAL PHYSICS AND DOSIMETRY
M.Sc. PROGRAMME

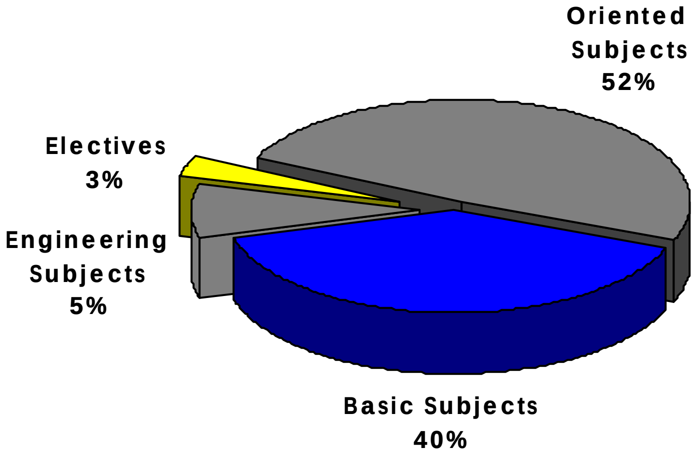
SUBJECT SEMESTER	**8**	**9**	**10**	NUMBER OF HOURS (TOTAL)
DETECTORS OF NUCLEAR RADIATION				**75**
RADIOBIOLOGY				**60**
ENVIRONMENTAL PHYSICS				**45**
BIOSTATISTICS				**45**
CELL PATHOLOGY				**45**
NUCLEAR MEDICINE				**30**
PHYSICAL FUNDAMENTALS OF DIAGNOSTICS				**60**
RADIOTHERAPY				**45**
SEMINAR				**90**
ELECTIVES				**210**
M.Sc. THESIS				

Poland, Krakow

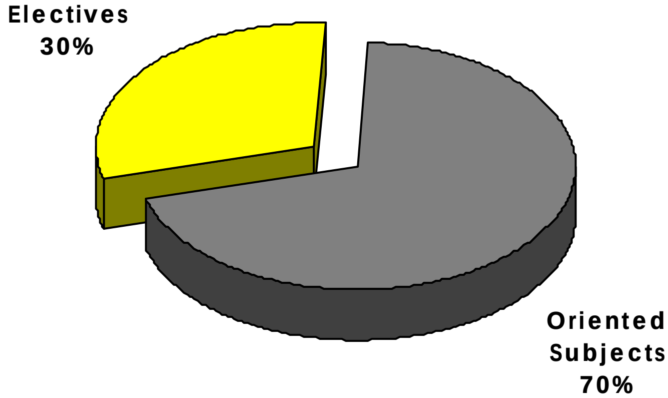
UNIVERSITY OF MINING AND METALLURGY KRAKOW

MEDICAL PHYSICS AND DOSIMETRY PROGRAMME
CONTRIBUTION OF TYPE OF SUBJECTS IN PROGRAMME :

B.Sc. :



M.Sc. :



Medical Radiation Physics

JAGIELLONIAN UNIVERSITY KRAKOW

MEDICAL PHYSICS PROGRAMME (ORIENTED SUBJECTS)

SUBJECT SEMESTER	7	8	9	10	NUMBER OF HOURS (TOTAL)
BIOPHYSICS	■				**30**
MATHEMATICAL MODELING OF PROCESSES IN BIOLOGY AND MEDICINE	■				**30**
THERMODYNAMICS OF BIOLOGICAL SYSTEMS	■				**30**
QUANTUM CHEMISTRY	■				**30**
MEDICAL PHYSICS LABORATORY	■	■			**90**
PHYSICS IN BIOLOGY AND MEDICINE		■			**60**
BIOCHEMISTRY		■			**60**
MEDICAL EQUIPMENT		■			**45**
PHYSIOLOGY		■	■		**45**
CELL BIOLOGY			■		**60**
CANCER BIOLOGY AND THERAPY					**60**
ELECTIVES					**30**
SEMINAR	■	■	■	■	**120**
M. Sc. THESIS			░	░	

75% core subjects
25% oriented subjects

Poland, Krakow

WARSAW UNIVERSITY

MEDICAL PHYSICS PROGRAMME (ORIENTED SUBJECTS)

SUBJECT SEMESTER	7	8	9	10	NUMBER OF HOURS (TOTAL)
CELL BIOLOGY AND PHYSIOLOGY					**30**
PHYSICAL FUNDAMENTALS OF DIAGNOSTIC					**60**
PHYSICAL FUNDAMENTALS OF RADIOTHERAPY AND RADIATION PROTECTION					**45**
BIOELECTRICITY AND FUNDAMENTALS OF BIOCYBERNETICS					**45**
STATISTICAL METHODS IN BIOLOGY					**90**
MATHEMATICAL MODELING OF PROCESS IN BIOLOGY AND MEDICINE					**60**
BIOCHEMISTRY					**30**
MEDICAL PHYSICS LABORATORY					**180**
SEMINAR					**120**
M. Sc. THESIS					

75% core subjects

25% oriented subjects

Medical Radiation Physics

ELECTIVES :

	Number of hours (total)
Medical Image Processing	**60**
Environmental Physics	**45**
Introduction of Biomaterials Science	**30**
Artificial Internal Organs	**30**
Technique of Membrans	**30**
Quick Analytical Tests for Medical Application	**15**
Mathematical Modelling of Process in Biology	**30**
Biosensors	**30**
Microdosimetry	**60**
Clinical Application of Computed Tomography	**60**
Computerization of measurements	**45**
Introduction to Aerosol Science	**30**
Electronic Dosimetry Equipment	**30**
Radioactive Waste Disposal	**30**
Radiation Protection in Hospitals	**45**
Accelerators	**30**
Cryogenics and Superconductivity	**45**
Physics of NMR and EPR	**30**

Poland, Krakow

M.SC. THESES IN MEDICAL PHYSICS AND DOSIMETRY 1994/95

-Influence of strong MW fields on selected bioindicator (Tradiscantia Statemen Hair Assay

-Analysis of n-penthan in exhausted air for medical diagnosis

-ACTH tracing for imaging of superrenal gland

-Study of reflective power of biological surfaces

-Comparative analysis of genotoxic hasard induced by ionizing radiation and petroleum products

-Modeling of detection process in physical and biological systems

-Clinical application of TLD dosimetry

THE HOSPITAL PHYSICIST IN PORTUGAL

J.GOMES da SILVA[1,2] , NUNO TEIXEIRA[1,2], J. MARIANO[2]

STATUS

The Population of Portugal is 10 million and the history of Medical Physics in Portugal dates from 1931. At the present moment, there are a very small number of Hospital Physicists in Portugal (26): 15 working in Radiotherapy, 10 in Nuclear Medicine and 1 in Radiology, all of them working in three main cities of Portugal: Lisboa (12), Porto (9) and Coimbra (5).

There are also 8 physicists in the protection area, in the Ministry of the Environment, where there exists a radioprotection and Nuclear Safety Department. They are in charge of the radioprotection film dosimetry, covering all the country (government and private institutions) and ambient radioactivity.

The national authority in radioprotection is the National Radiation Protection Commission. The legal decrees D.L. 348/89 and D.R. 9/90 implement the Community directives about radioprotection in Portugal.

HISTORY

1931-1933:

IPOFG (Lisbon) New building for the Radiodepartment; Physics section (Radium Dosimetry and Radioprotection) with several physicists (not H.P.); Roentgentherapy Section.

Later:

Nuclear Medicine laboratory with several physicists; Radioprotection section.

1958:

First Cobalt machine in Portugal; First H.P. in Radiotherapy (IPOFG, Lisbon)

After 1960:

IPOFG (Coimbra) 2 Ro therapy machines, 1 Co unit, 1 H.P.
IPOFG (Porto) 1 Co unit, 1 H.P.

Until 1974 - 1 H.P. in Angola, 1 H.P. in Mozambique.

LEGISLATIVE BACKGROUND CONCERNING THE HOSPITAL PHYSICISTS

In Portugal a regular training scheme has not yet been implemented. The medical physicists working in governmental hospitals received their training abroad or from colleagues in the hospital where they started work. There are also private clinics, some of them employing physicists full time (3) and others having a part-time assistance or no co-operation with medical physicists at all.

The hospital physicists working at the governmental hospitals are Health Civil Servants and their career is named Tecnicos Superiores de Saude. They must have an university degree ("Licenciados") in Physics or Physical Engineering (4-5 years of study).

For the last two months our government has been modifying the career of the hospital physicists. That career was initially ruled by the legal decree D.L. 414/91. In September 1994 two decrees were issued in the Official Journal about the training course for new hospital physicists (291/94 and 796/94), and a process of admission for new physicists is starting just now. Last October, in the Official Journal another decree was published (931/94) with the final regulation of the H.P. career. The career system requires as further qualification ("Especialista", Specialist) an in-service training course of two years, with courses on different physical and medical areas, as well as legislation, administration and financial areas. In Fig. 3 an inter-comparison is shown between the levels of our career and the recommendations of EFOMP.

STATUS AND THE ACTUAL NUMBER OF HOSPITAL PHYSICISTS IN PORTUGAL

The number of hospital physicists in Portugal is given in the following tables. As we can see, the number of hospital physicists is very small (26) when we consider the EFOMP recommendations (more than 70). From those 26, only 9 (35%) are working less than 5 years (time that we think necessary to prepare a hospital physicist), 15 (58%) are working in Radiotherapy, 10 (38%) are working in Nuclear Medicine and 1 (4%) are working in Radiology.

Although we do not have the exact number of new patients and equipment, we can see clearly that there is an enormous deficit of Hospital Physicists in Portugal.

At the present moment one of the authors is establishing contacts with academic authorities (Universidade Nova de Lisboa) in order to promote M.Sc. or Ph.D degrees in the H.P. areas.

Under our point of view it is also necessary to improve our career (higher salaries and more attractive); to define responsibilities (H.P./Radiotherapists/Technicians) and to establish medical physics departments in government hospitals. It is necessary also to reorganise the actual H.P. association (actually is a section of medical radiological society) or to create a separate organisation when the number of H.P. grows up.

FUTURE NEEDS

The number of medical physicists in Portugal has to be increased in order to accomplish with the EC Directives and the role and status of the Qualified Expert in Radiophysics has to be regulated. The first steps in this direction will be opening new vacancies and organising of training courses. For this MSc/Ph.D schemes need to be developed together with the appropriate Universities (UNL). These steps would be facilitated if Medical Physics Departments with defined responsibilities were established in the Governmental Hospitals and perhaps with reorganisation of the professionals in a separate association. Last, but not least, improvement of the basic salaries will attract more young people to the profession.

The present paper is a personal point of view about the Portuguese hospital physicists (HP) position and does not express the Portuguese health authorities opinion, as the authors are participating in this meeting as a single physicist and not as a civil servant and/or governmental representatives.

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(2) Servico Fisica, Dept. Radioterapia, IPOFG, P-1093 Lisboa Codex, PORTUGAL, fax 1 7266307

Medical Radiation Physics

Appendix

Table 1:
COMPARISON BETWEEN EFOMP RECOMMENDATIONS AND THE PORTUGUESE H.P. CAREER

COMPETENCE LEVEL	**TRAINING/** EFOMP RECOMMENDATIONS	**EXPERIENCE** PORTUGUESE H.P.CAREER
1	Relevant first degree or equivalent (Bsc, 3 years)	University Degree in Physics "Licenciado" (4/5 years)
2	1 + 2 years directed training	1 + 2 years course/training + examination: Especialista Gov. Post: Assistente
3	2 + 2 years subsequent practical experience	2 + 3(*) years + curriculum appreciation. G.Post: Assistente Principal
4	3 + 4-5 years of subsequent experience (e.g. Head of a small section)	3 + 4 (*) years + examination G.Post: Assessor
5	4 + greater responsibility and a mature overview (e.g. Head of department or large Section)	4 + 3 years (*) + Examination and Thesis G.Post: Assessor Superior
QUALIFIED EXPERT	Level 3	??? not legally established

(*) The number of years depends on the permission of the Government.

The IPOFG (Lisboa) with academic authorities (UL, UNI,) is promoting training/research programmes (1 academic year) for students (5th year), after completion of their scholar studies programme (4 years). Financial help from Portuguese Cancer League (LPCC) and other possible organisations are in progress at the present moment.

Nuclear Medicine (Portugal)

	Physic	Gamma C	Bone D
Lisbon			
IPO	2	3	0
FML	1	2	1
HSC	0	1	0
I.Cor.	0	1	0
F.Aerea	0	1	0
Priv.1	0	2	0
Total	3	10	1
Porto			
IPO	1	1	0
HSJ	2	3	1
Priv.1	0	1	0
Priv.2	1	1	0
Priv.3	0	1	0
Total	4	7	1
Coimbra			
HUC	0	3	1
FCM	1+2(<5y)	3	0
Priv.1	0	1	0
Total	3	7	1
TOTAL	**8+2(<5y)**	**24**	**3**

Considering just Gamma cameras, we obtain the number of 12 Hospital Physicists in Nuclear Medicine, according to the EFOMP.

Radiology (Portugal)

Hospital Physicists	1
CT Systems	68
MR Systems	14
Angiographic systems	20+8(card.)
General X-ray	?

If we just consider the number of Diagnostic Radiology equipment (Digital X-rays + CT + Mammography) serving 500 000 people, we should have 20 Hospital Physicists in Radiology.

Table 2: RADIOTHERAPY (PORTUGAL - 10,000,000 PEOPLE)

	Phys.<5y	Phys.>5y	Lin.Acc.	Co-60	Xray	Simul.	Af.Load	Comp.T.P	Wat.Tank	Dos./I.C	TLD Sist.	S.S.Dos.	N.Pat/y
Lisbon													
IPO	2	4	2(+1)	5(+1)	0	1	3	2	1	6	2	2	3000+600
HSM	1	0	1	1	0	1	1	2	1	2	0	2	1000
Priv.1	0	0	0	1	0	0	0	0	0	0	0	0	400?
Priv.2	0	1	1	1	0	0	0	0	0	1	0	0	400?
Total	2	6	4(+1)	8(+1)	0	2	4	4	3	9	2	4	
Porto													
IPO	2	2	3	2	0	2	4	2	2	2	2	0	1862+993
HSJ	0	0	0	1	0	1	0	1	1	1	1	0	Star/1994
Priv.1	1	0	0	2	0	0	0	0	0	1	0	0	400
Priv.2	0	0	0	1	0	0	0	0	0	0	0	0	Star.1994
Total	3	2	3	6	0	3	4	3	3	4	3	0	
Coimbra													
IPO	1	1	1	2	1	1	2	2	1	2	1	1	1111+164
Total	1	1	1	2	1	1	2	2	1	2	1	1	
Total	6	9	8(+1)	16(+1)	1	6	10	9	6	15	6	5	8973+1600
WTE (EFOMP)			0.8	0.4		0.4	0.4	0.4					1.2/2.5
Num.Phys			7.2	6.8		2.4	4	3.6					10.7/4

If we consider the EFOMP numbers, we can see that there is just a small part of the necessary Hospital Physicists working in Portugal. Considering the existence of 400 new patients in each institution where we do not have good information, the number of Hospital Physicists should be 24+ 15 = 39, and at the moment there are just 16.

MEDICAL RADIATION PHYSICS AND ENGINEERING IN ROMANIA

C.MILU[(1)] and M.ANTONEANU[(2)]

STATUS

In Romania ionizing radiation is widely used for both diagnosis and treatment, e.g. X-ray diagnosis, radiotherapy and nuclear medicine. According to the 1993 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (1), before 1989, in a population of more than 23 millions of inhabitants in Romania, were reported as existing; 2, 746 X-ray diagnostic units and additionally, 1,100 dental units, 202 X-ray Teletherapy units, 20 Cobalt-therapy laboratories and 2 LINACs, as well as 39 nuclear medicine clinics. The situation is given in Table 1. After 1989, the total number of units is roughly the same, but the structure of medical devices has been slightly improved, especially by the acquisition of about 25 new CTs and of some other modern X-ray diagnostic machines.

The annual number of medical radiation examinations and treatments, reported for 1990 is: 11,392 thousand X-ray diagnostic examinations (which means about 500 examinations per 1,000 population and a strong decrease from 70: more than 1,000 exams), 55.8 thousand radioisotopes examinations and 157 thousand therapeutic treatments (about 2/3 of them by X-ray). The situation is presented in Table 1.

In the medical radiation field there are approximately 165 medical radiation physicists and engineers. Their distribution by specific domains of professional activity is presented in Table 2.

The 41 medical radiation physicists and engineers from diagnostic radiology and imaging, are mainly from CTs Network (approx 20 labs), which was developed during the last 8 years. All the other X-ray diagnostic units have no medical physicists.

All the 33 physicists and engineers from radiotherapy are involved in Cobalt-60 teletherapy, and LINACs. By a regulation of the Ministry of Health, each Cobalt-therapy laboratory must have engaged at least one radiotherapy physicist.

The 26 physicists and engineers from nuclear medicine, as in X-ray diagnosis, appeared during the last 8 years, due by the introduction in this field of some new techniques of investigation.

All the 32 physicists and engineers from radiation safety belong to the Radiation Hygiene Laboratories Network (21 labs) of the Ministry of Health. This National

Network is co-ordinated by the Institute of Hygiene, Public Health, Health Service Management, in Bucharest. The staff members of this network carried out the national studies on medical exposure of the population of Romania (investigations on frequency of procedures, patient dose measurements, risk assessments, quality assurance and control). Part of their research results are included in UNSCEAR Reports.

The repair and maintaining of all installations is provided by specialized teams of the Ministry of Health, belonging to the county Medical Directions. In Bucharest, in addition to such a team, there is also a Central Service Laboratory of the Ministry of Health, which performs checking of the equipment, special repairs and supplies, technical assistance for setting-up of X-ray machines.

The majority of the 165 medical radiation physicists and engineers from Romania are active members of one of the following national societies and professional associations:

- Romanian Medical Physicists' Association (approx.60 members);
- Romanian Society for Radiobiological Protection (an Associate Society to the International Radiation Protection Association, having 370 members, 50 being physicists and engineers from medical radiation field);
- Romanian Society for Clinical Engineering and Medical Computing (about 100 total members, 30 from medical radiation).

All medical physicists, engineers and other radiation specialists (radiochemists) radiobiologists) have a university education (University or Polytechnic Institute), with an M.Sc degree.

EDUCATION

Post-graduate specific education in the medical radiation field is actually acquired in the process of work, as unfortunately, in Romania there is not existing now for this purpose an organized training system. Due to the lack of such an official education system, the certification and recognition of the profession encounters in practice great difficulties .

This situation must be improved very soon, as the number of specialists requested in radiation medicine will increase during the next years. Good career opportunities in the profession are available in the near future, the Ministry of Health already ordered some new and very complex equipments, which certainly need to be operated and maintained by appropriate persons (physicists and/or engineers). It was also realised that physicists are requested and even in conventional X-ray diagnosis, for quality assurance and control activities.

With the aim to improve the specific training of workers from medical radiation, several courses and seminars were organised by the professional societies and associations and/or by different medical research institutes. We can mention here the last Workshop organised by the Institute of Hygiene, Public Health, Health Services and Management-Bucharest from 18th to 21st of October 1994 on "Radiation protection and quality assurance in diagnostic radiology". 30 Physicists and engineers and 20 radiologists attended the meeting. The lectures were presented by 6 experts from U.K. Belgium, Italy and Switzerland, and the kind support from the Clinical Science Foundation, London and The International Atomic Energy Agency-Vienna. Similar further assistance would be very useful.

A part of medical radiation physicists and engineers from Romania succeeded to have Ph.D degree in different specialities (not in medical physics). Some of them were trained in several scientific specialities (not in medical physics). Some of them were trained in several scientific institutions abroad and/or attended international meetings. A reduced number of members of other national societies (like, American Association of Physicists in Medicine).

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Appendix

TABLE 1: Radiation medicine units and procedures in Romania (in 1990, 23 Million inhabitants)

	Diagnostic Radiology		Radiotherapy		Nuclear Medicine (number of laboratories)	
	X-ray diagnostic	Dental	Conven-tional X-ray	Co-60	LINAC	
Number of units	2746	1100	202	20	2	39
Tot. No exams. or treatments (1000)	10688	704		157**		55.8*

TABLE 2: Medical radiation physicists and engineers in Romania (Sept 1994)

Medical Physics						
	Total No	Diag. Radiol/ Imaging	Radio-therapy	Nuclear Med.	Rad. Safety/ hygiene	Equip. Maintenance
Med. Rad. Physicist	100	23	25	19	30	3
Engineer	65	18	8	7	2	30

MEDICAL PHYSICS IN ROMANIA AND AT THE "AL.I.CUZA" UNIVERSITY OF IASI

C. COTRUTZ[(1)], P. FRANGOPOL[(1)], G. POPA[(1)], M. SANDULOVICIU[(1)], G. ABUSAN[(2)], G. MATACHE[(3)]

STATUS

Romania (23 million inhabitants) is probably of the few countries in Europe which has not yet recognised the medical physicist profession as a necessity, by law and/or by internal orders of the Ministry of Health (1).

None of the major Romanian Universities has medical physics as a distinct area of education and research. Similarly, until now, no special training has been given to the graduated physicists, based on a syllabus scheme in order that the trainee could acquire an adequate academic knowledge of the application of physical sciences and engineering in medicine.

The Romanian Medical Physicists' Association (RMPS), organised in 1990, is the professional body for the radiation physicists working directly in hospitals and related fields to medical physics (around 35 from a total membership of 61). Thus, Romania has only slightly more than 1.5 medical physicists per million inhabitants.

Despite the fact that oncological treatments with Radium started early in 1927, with sources donated by Maria Sklodowska-Curie to the hospitals of Bucuresti, Brasov and Cluj, the medical physicists appeared in the hospitals, only later in '60's, as a necessity to use the cobalt therapy apparatus, just introduced in the Oncological Institutes of Bucuresti and Cluj.

The first years were very difficult since it was necessary to surpass, firstly, the suspicions and lack of confidence of the medical doctors and secondly, the non-existence of scientific literature and techniques for a real physical and clinical dosimetry. These heroical years of very good self-education (1960-1990) received an unexpected confirmation: before and after the fall of the "iron-curtain" (1989), a lot of medical physicists emigrated and now are working as medical physicists in countries with tradition in the field, e.g. USA, Switzerland, France, Israel, Germany etc.

It is worth mentioning a very important step in the field: the Ministry of Health organised at the end of '70s some Institutes and regional laboratories of Hygiene and Public Health (Bucuresti, Iasi, Timisoara, Cluj, etc.), which are involved mainly with radiation protection, occupational health, food contamination, water and air pollution, radiation hygiene Inspection of radiation installations, etc. Here are also working medical physicists mainly for quality assurance. The regional laboratories (17) now, have special duties and new names: centres of oncology and external radiotherapy with ^{60}Co, which by decision of the Ministry of Health "should have a medical physicist." In the last decade an increased number of nuclear medicine laboratories within Romania have been organised in the regional hospitals (with M.D., chemists, biologists and a few medical physicists).

The development of the applications of radiation in other fields as well, led the State Committee for Nuclear Energy to organise with the Institute of Atomic Physics Magurele-Bucharest and the Faculty of Physics of the Bucharest University, a common postgraduate training course (M.D., chemists, engineers, biologist, etc.) in the utilization and application of radioisotopes for persons who will have responsibilities in the application of radiation (industry, hospitals, Universities). The course is effective, every year since 1956, but is not useful for medical physicists (well known syllabus from the Faculty of Physics courses) and for the M.D's is hard to understand (lack of the elementary background). Until today, the true education remains the same: within the internal seminars of the Institutes as well as during the Internal National Conferences of the RMPA.

It should be mentioned that within the National Centre of Physics, the Institute of Atomic Physics and other Institutes located at Magurele (15 Km from downtown Bucharest), a strong nucleus in radioprotection, dosimetry, etalon sources, quality assurance and control, nuclear medicine, preparation of radioisotopes, radiopharmaceuticals, labelled compounds and dosimeters, has been developed in the last 40 years. Currently, various apparatus (electronic devices or big machines - e.g. betatrons for oncological use etc.) are realised. Also, internal contamination in the whole body (thyroid and lungs) biokinetic studies for committed effective doses, are currently measured using in-house international homologated equipments with original and/or well known methods (e.g. the **BO**ttle-**M**anechin-**AB**sorbtion, **BOMAB** type of calibration, etc.) All the above activities are related also with direct applications in medical physics. There are numerous books from Romanian authors on Radiation Physics, Radiation Protection (2,3) and Medical Engineering, also original papers published in leading international journals, proving an international recognised expertise in the domain. Only the latest published materials (selected) are mentioned in the bibliography (4-14).
Disintegrated after the 1989 Revolution, the Romanian Agency for Atomic Energy was recreated, by Government Decree on October 30, 1994. It is a new and real hope for reinvigorating the Medical Physics in Romania according to

European standards. Until now, the existing national regulatory body for nuclear/radiation safety is the National Commission for Nuclear Activities Safety Norms, Law No. 61/1976; b) Norms for Radiation Protection, 1976; c) Work Rules with Nuclear Radiation Sources, 1976; amended in 1979 and 1981; d) Norms for Transport of Nuclear Materials, 1975; e) Rules for Issue of the Permits to Work in the Nuclear Field, 1990.

In the last three years advanced technology has been introduced in all medical domains. It became necessary to create a University Medical Physics Department in order to train physicists able to ensure the proper and safe use of new technology in Romania.

THE EDUCATION IN THE UNIVERSITY OF IASI

The ministry of education received the proposal made by "Al.I.Cuza" University to enlarge the scope and activities of the Department of Biophysics, which is part of the Faculty of Physics, to become "Biophysics and Medical Physics Department", including in this way graduate and postgraduate educational and research projects in both Medical Physics and Biophysics, beginning with the 1995 University year.

A radiation Medical Physics laboratory will be set up at the "Al. I. Cuza" University of Iasi, Department of Biophysics and Medical Physics, the first such laboratory in a Romanian University, to train future physicists specialising in Medical Radiation Physics. This laboratory will be realised and with the assistance of the International Atomic Energy Agency (IAEA), Vienna (1995-1996).

A scientific cooperation and practical training of the students from Iasi University with the Oncological Institute in Bucuresti, a methodological oncological Centre for Romania, also with the Oncological and Radiotherapeutical Centre in Brasov has already started.

To achieve the immediate above mentioned objectives e.g. to engage in educational and research work, directed to accomplish the requirements for MSc and PhD thesis, besides the broader international assistance requested, important support has already been received from:

1. IAEA Vienna, with a project for technical cooperation (1995-1996), a model one for Europe and the Middle East, decided to assist our Biophysics Department to set-up a Medical Physics Laboratory, for training medical physicists, in order to meet Romania's requirements for medical physicists for the next ten years.

Medical Radiation Physics

2. JEP-TEMPUS II Program (1994-1997) with the kind help of ERASMUS Project coordinated by Patras University, Greece, for training in medical physics each year 5 students from our university, for 8 months. It should be mentioned that another 9 students from Technical Universities of Romania are attending the training in Patras, only in Bioengineering. They come from: Iasi (2), Bucuresti (2), Craiova (1), Timisorara (2), Cluj-Napoca (2).
3. Scientific Collaboration in medical physics between Iasi, Patras and Thessaloniki Universities.
4. Scientific collaboration in medical physics within the frame of Governmental accord between Greek and Romanian Ministries of Research and Technology, with the University of Patras (Prof. B Proimos).

As can be seen, the points 2-4 fall within the framework of a general effort to establish University Centres of Medical Physics and Bioengineering in Romania and particularly in Iasi.

As far as we know it is a unique example of pragmatic cooperation and collaboration now, in Europe, in this field, as a concentrated and rapid effort toward the integration of Romania within the International standards in medical physics, Greece playing a particularly very important role in our very beginning: the IAEA expert from Romania for medical physics was Professor Basil S. Proimos, from Patras University, Greece.

It is our strong hope that the European Federation of Organisations for Medical Physics (EFOMP), in collaboration with the International Organisation for Medical Physics (IOMP), the International Federation for Medical and Biological Engineering IFMBE), the World Health Organisation (WHO), and different other National West European Associations in Medical Physics, along with other international associations, will try to find a way to help in promoting our efforts recommending and/or advising the Romanian authorities to establish by law the necessity of recognising the profession of medical physicist in all the hospitals and clinics in Romania. The Medical Physicist profession is well established and without it the health care service is impossible to be done normally. Medical physics can be described as the scientific discipline which is concerned with the application of the concepts and methods of physics in medicine; also, medical physics is a health care profession and the medical physicists whose training and function are specifically directed towards health care is entitled to an official recognition as a specialists; the formal entry training into the profession of medical physics has physical sciences as an essential component of the academic education (15-17).

Romania, Iasi

Establishing and organising in Romania medical physicist education, profession and career (higher salaries and more attractive positions), according to the already existing international standards, is our first priority for the near future.

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Medical Radiation Physics

THE EDUCATION OF MEDICAL PHYSICISTS IN RUSSIA

T.G.RATNER[1]

STATUS

Medical physics in Russia has been developing for the last twenty years. Specialists work mainly at radiation therapy and nuclear medicine departments in oncological hospitals. There are about 200 hospitals which need medico-physical services. Most of them are in the European part of Russia. The specialists' work is various including physics, engineering, teaching etc. As a rule medical teaching training is provided at the working place. There are also one-month courses organised by the Institute for Post-graduate Medical Education. They are only held once every two years which appears to be quite insufficient. That is why the Association of Medical Physics in Russia (AMPR) and the Cancer Research Centre in Moscow decided to organize appropriate education and training for physicists working in Radiation Therapy Departments.

The Association was founded in 1991. The first President was the late Professor A. Gurvich. At present the AMPR has more than 250 members. This is not a large number taking into consideration that there are more than 200 hospitals and oncological dispansers which need qualified radiation medical physicists as well as many scientific institutes for research and development of medical equipment.

One third of the Association's members are hospital physicists most of these working in radiation therapy departments. Another one-third are specialists developing various medical equipment and the rest are academic staff (professors and lecturers) working at chairs of Physics in Medical Institutes. The present President of AMPR is Dr V.A.Kostylev, Head of Medical Physics Department in the Cancer research Centre of the Russian Academy of Medical Sciences and the Secretary-General is T.G.Ratner, Ph.D. and Senior Research Fellow at the same department.

The Cancer Research Centre is the largest oncological institute in Russia. There is a clinic with 1000 hospital beds for all kinds of treatment of oncological patients and a big emergency department. The radiation therapy and medical physics departments are well equipped. There are simulators and a CT unit for topometry, seven various systems for computer dose planning and dosimetric equipment. For tele-irradiation 3 liner accelerators, 6 gamma-units and proton beam ITEP are used. For intra-cavitary and interstitial therapy are used Co-60 and Cf-252 needles, 2 Selectrons with Cs-137, low and high-dose microselectrons with Cs and Ir-192, AGAT with C0-60 and ANET-VA with Cf-252(with a gamma-neutron source).

EDUCATION

At present there is no specialized undergraduate education in medical physics in Russia. Post-graduate education is rather sporadic. One-month courses are organised for physicists working in radiation therapy only. The Association also organizes short 1-2 week refreshing courses and courses for training in particular subjects only for physicists and doctors, i.e.: calibration of dosimetric equipment; quality control of tele-irradiation; manual and computer dose-planning; intra-cavitary irradiation; new regimes in radiation therapy; equivalence of biological doses; new modes of equipment; hypertermia etc.The best qualified specialists from Moscow Institutes provide tuition for those courses. Up to now more than 100 specialists have received a certificate.

At present one of the main tasks of the Russian Association is the developing of a National Educational System which will be oficially approve. The Association accepts in general the EFOMP recommendations for a 4-year basic course in physics followed by a 2-year study of medicine, biology and special techniques and then two years of training at a clinic. Special attention is to be paid to the education or rather the preparation of physicists to work in clinics and especially in clinical research. During the two years the students will study various subjects: special techniques, biology, radiobiology, medical topics, anatomy, physiology, oncology, roentgenology etc. Their substance is very different and in two-years' time the students' psychology would be changed very much.

One of the biggest problems that physicists face at the beginning of work is the lack of understanding (at times) with the medical doctors. To our opinion physicists should be prepared to understand that the main strategic tasks in clinical work are clinical problems while technical and dosimetric problems are subsidiary. Another important problem for physicists is to acquire knowledge of relations with the patient and of patient behaviour. We are trying to include such topics in the envisaged post-graduate education for medical physicists so that they will be prepared to work in clinics as true partners to medical doctors.

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POST-GRADUATE EDUCATION IN MEDICAL RADIATION PHYSICS IN THE SLOVAK REPUBLIC

V. LAGINOVA [(1)] and I.MYDLO [(2)]

STATUS

Slovakia has approximately 5.5 million inhabitants. The departments, equipment and number of physicists in Slovakia are shown on Table 1 below:

Table 1

Department	Number of Departments	Equipment		Number of Physicists
		Type	No.	
Radio- diagnostics		XRU CT MRI	1500 27 2+3*	5.5
Radiotherapy	14	Cs/Co LA XRU AF SIM TPS	3/14 3+5* 16 10+4* 3+1* 12	19
Radiation Physics	1	dos TPS	3	4
Nuclear Medicine	12	GCC IVA GC	20/9** 25 10	14
Radiation hygiene	6			28

Key to the Table:

XRU - X ray unit; CT - Computer tomography; MRI - magnetic resonance; Cs - 137 cesium unit; Co - 50 colbalt unit; LA - linear acceserator; AF - afterloading HDR, LDR, PDR, SIM - SIMULATOR; TPS - Treatment planning system; dos - Dosimetry. GCC - gamma camera computer; IVA - in vivo apparatus; GC - gammagraphy; + will be installed shortly, ++ - spect.

The only independent department of Radiation Physics is the one at the National Cancer Institute (hospital of St. Elizabeth), the rest of the physicists presented in the table 1 are members of the Departments of Radiotherapy, or Departments of Nuclear Medicine. The distribution of the respective equipment in Slovakia is shown below:

BANSKA BYSTRICA	3 TPS 2 GCC 2 Co 2 IVA 1 GG 1 AF 1 LA willbe installed
BRATISLAVA	5 GCC 6 IVA 1 LA 2 AF 1 SIM 2 Co 3 TPS 3 GG 2 LA will be instaled
KOMARNO	1 Co
KOSICE	2 GCC 1 GG 4 IVA 1 LA 2 Co 1 SIM A AF 2 TPS
LUCENEC	1 Co
MARTIN	2 GCC 1 IVA 1 TPS 1 Co 1 Cs 1 AF
MICHALOVCE	3 IVA 1 GCC 1 TPS 1 AF 1 Co
NITRA	2 GCC 1 IVA 1 GCC 1 TPS 1 AF 1Co
POPRAD	1 GG 2 GCC 2 IVA
PRESOV	1 GG 1 VA 1 GCC 1 LA will be installed
RIMAVSKA SOBOTA	1 Co 2 IVA 1 AF 1 TPS
ROZNAVA	1 GG 2 GCC 1 Co 1 AF
TRANCIN	1 SIM 1 Co 3 TPS 2 AF 1 LA
TRANAVA	2 IVA 1 GCC 1GG
ZILINA	1 Co 1 Cs 1 AF 1 TPS 1 LA will be installed

EDUCATION

The undergraduate education of physicists can be realised at various faculties of the University: Mathematico-physical Faculty, Facualty of Natural Sciences, or Electrotechnical Faculty. At the end of this education the candidates are granted the degree of RNDr (rerum naturalium doctor) - equal to MSc. During these studies the students are educated in dosimetry, nuclear physics and electronics. Consequently, arriving at health service institutions, the physicists have no experience in the field of any work with patients and are lacking the knowledge of anatomy, physiology or pathophysiology. Therefore, before starting the work with patients, they are obliged in 6 months to complete their education finalised by a test.

STRUCTURE OF THE POST-GRADUATE EDUCATION

There are two alternatives of post-graduate education in Slovakia:

Slovak Republic

Alternative 1: 4 - 6 semestral education in clinical dosimetry, radiobiology, the use of computers in medicine, etc. This education is closed by a the defense of thesis and examination. The education is usually organised by a faculty of the particular university.

Alternative 2: Three years of postgraduate education at the Institute of Postgraduate Medical Education [IPME], following which a candidate is granted the specialisation of a physicist with permission to work in radiotherapy, nuclear medicine and radiation hygiene. This education includes a 4-week stay in one of the specialised institutions, participation on special courses [brachytherapy, clinical dosimetry, therapy planning, etc.], organised by the IPME or by the ESTRO. The education is organised in two sections of theoretical and practical areas (general section and special section). They include the following topics:

1. General Section:

-a. basic anatomy: **(See appendix 1)** topography of organs on the basis of body orientation points and lines related to the: brain, upper respiratory tract, lung, gastrointestinal system, urinary tract, female and male reproductive organs, lymphatic system and thyroid gland.
-b. health service organisation, focused on the field of radiotherapy and oncology.
-c. psychological aspects in cancer patients.
-d. ethios of health service personnel.
-e. basic emergency services.

2. Special section:

-a. basic clinical oncology [cancer aetiology, pathology, diagnostics and treatment methods]
-b. basic radiobiology [effects of irradiation in cell, damage following irradiation, radiosensitivity, tolerance of critical organs, etc.]
-c. basic radiophysics [corpuscular and electromagnetic radiation, interaction of ionising radiation with matter, absorption coefficients, LET, etc.]
-d. dosimetry [absorbed dosis, equipment, data for planning systems, etc]
-e. therapeutic application of ionising radiation [equipment, techniques, therap planning, fractionation, reactions, etc.]
-f. standardisation of dosimetry
-g. radiohygiene [directives, safety, controls, etc.]
-h. statistical methods
-i. practical knowledge [dosimetry, planning, equip. control] - see appendix 2

A thesis and oral examination finalized the course.

Medical Radiation Physics

The above listed syllabuses have been elaborated and our present aim is to adjust the education to the standards of the EFOMP, ESTRO and EC, to be able to provide internationality acceptable certification.

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APPENDIX 1:

a/ basic anatomy

CNS (brain, spinal cord...)
Skeleton (head, spine, pelvis, extremities)
upper respiratory tract (epipharynx, larynx, trachea)
lung (lobar, bronchial arbor)
gastrointestinal system
(oral cavity, oropharynx, hypopharynx,oesophagus, stomach..)
urinary tract (kidney, gall bladder...)
female and male reproductive organs
lymphatic system (lynph, nodes in neck, thorax and abdomen)
thyroid gland
physiology

APPENDIX 2:

a/ diagnostic methods

X-ray, CT - MRI and nuclear medicine
treatment methods
surgery, radiotherapy, chemotherapy etc.

b/ basic radiobiology

4 R, reversible, irreversible damage, genetic changes etc.

c/ basic radiophysics

ionization and non ionization radiation, interaction, scatter, radiation protection, dose quantities
quality factors
medical electronics

Slovak Republic

d/ **dosimetry**
equipment, dosimetry theory and methods in radiotherapy, beam characteristics; in vivo dosimetry

e/ **therapy application**
X-ray, accelerators, afterloadings, target volume, critical organs localization, 2 D, 3D, treatment planning systems and algorithm...

f/ **standardisation** - dosimetry
quality standards
equipment
laws and legislative

g/ **radiohygiene and protection**
staff and patients
training and test
electrical, mechanical and biological safety

h/ **statistical methods**

i/ knowledge from all previous courses

MEDICAL RADIATION PHYSICS IN SPAIN

P. FERNANDEZ LETON[(1)] and M. RIBAS MORALES[(2)]

STATUS

The population in Spain is over 38 millions of inhabitants. In general, medical physicists belong to The Spanish Society for Medical Physics (SEFM) that has 221 members distributed in the following areas:

Radiotherapy (RT) 96(43.4%)
Diagnostic radiology (RD) and Radiation protection (RP) 49 (22%)
Nuclear Medicine (NH) 10 (4.7%)
Teaching at University 48. (22.6%)
Other areas (civil servants, instrumentation, etc) 18 (8.1%)

At the end 1992, according to the data given by the Spanish Assocation for Radiotherapy Oncology (AERO), there were 78 RT centres (public and private), 43 of them also included Brachytherapy and the number of equipment in external RT was:

Conventional X ray	43
Cobalt units	84
Linacs (photons 6 MV)	6
Linacs (photons + electrons)	40
Simulators	45
Treatment planning Systems	66
Radiation field analyzer	38
Number of treated patients per year	39524

At the end of 1994, according to the data given by the Spanish Society for Nuclear Medicine (SEMN), there were 70 centres (public and private), each with two gamma cameras at least.

Concerning the physicists who are working in hospitals within ionising radiation field, they can be grouped into two different situations, about half:

- an independent Department of Medical or Radiation Physics and Radiation Protection, for covering it altogether, in which case have 3-6 people, or
- one department of Radiation Protection and other physicists working in RT, NM Departments who belong to each of them.

Table 1 below shows the number of physicists per hospital

	1 physicists	2 physicists	3 physicists	4 physicists	5 physicists
No. Hospitals	16	15	12	6	8

REGULATORY BODIES IN RP

In our country there are two regulatory bodies related to RP:
Council of Nuclear safety, responsible for RP of workers and general public, Ministry of Health, responsible for RP of patients.

GENERAL EDUCATION

Up to 1993, the majority had got a degree in Physical Science or equivalent .
Since 1994 a draft Royal Decree from the Ministry of Health concerning a "**training and attainment of Diploma in Hospital Radiation Physics",** allows people having a degree in Physical Sciences, Engineering or Chemical Science to take a post-graduate educaiton on medical radiation physics. The SEFM has complained of the access for chemists.

POST GRADUATE EDUCATION

Up to 1993 this was provided individually by different ways i. e. :

- following a formal post-graduate course abroad,
- special programme in a public notice as residents in 70's (M. Health),
- self taght,
-spending and working sometime with experienced colleagues in recognised national or foreign centres, etc.

Since 1994, according to the draft above mentioned, post-graduate education is provided like a "residence" in a hospital (similar to medical residence) during 3 years with a theoretical programme and practical period in-service (1 year and a half in RT and 6 months in each other areas DR NM and RP). Every year 14 people are accepted and a workable full-time contract is established between the resident and the hospital.

Theoretical programme (temporary)

General topics in Anatomy and Physiology, Rdiological Physics, Radiobiology and instrumentation in radiologialphsics. Specific in each radiation area.

Medical Radiation Physics

Radiotherapy: radiation sources, physical dosimetry, clinical dosimetry in external RT, clinical dosimetry in brachytherapy, treatment planning systems and quality control.

Diagnostic Radiology: equipment and special procedures, image receptor systems, components and factors affecting the image, physical dosimetry

ACTIVITIES IN PROFESSIONAL DEVELOPMENT

The SEFM organizes every two years national meetings and this year has also organised a post-graduate course in specific topic: Electrons Dosimetry.

CERTIFICATION AND RECOGNITION OF THE PROFESSION

Until now the profession is not officially recognised, but this point is taken into account in the draft mentioned. The career opportunities in the profession are occasional

SCIENTIFIC CONFERENCES

The SEFM has participated in some scientific meetings, invited by other Scientific Societies related to ionising radiaiton field.

FUTURE NEED FOR MEDICAL PHYSICISTS

Up to year 2000, according to the draft Royal Decree a maximum of 56 physicists will have finished their training, however the SEFM has made a first overview of the necessary specialists in these fields and in their opinion a minimum number of 90 (43 in RT, 25 in NM and 22 in DR) would be necessary, depending both on equipment load, number of patients and procedures in each area.

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MEDICAL RADIATION PHYSICS IN SWEDEN

I.-L. LAMM[(1)]

INTRODUCTION

The Swedish Hospital Physicists Association is the Swedish professional body for physicists working in health care The total membership is 213 (August 1994), and around 140 of the members are working clinically as hospital physicists. The remaining membership consists of physicists or engineers (required to be at least university graduates in physics or equivalent) with interest in the field of hospital physics, as well as of students in radiation physics. The Swedish Hospital Physicists Association is the Swedish member of EFOMP.

Hospital physicists, as we are called in Sweden, have traditionally been working in the field of clinical medical radiation physics, especially in ionising radiation applications, the classical areas being radiation therapy, nuclear medicine including radionuclide therapy, diagnostic radiology and radiation protection. With the advent of readily accessible computer power, imaging in a wide sense has been steadily growing in all areas of the clinical responsibilities. Today hospital physics also covers non-ionising radiation applications such as MRI, ultrasound and laser.

NUMBER OF HOSPITAL PHYSICISTS

In 1993, EFOMP made a survey of the number of "Qualified Experts in radiophysics, QE(r)s" in the member countries. This survey asked for the number of all trained medical radiation physicists according to the rules of the country, as well as the number of trained medical radiation physicists with at least five years of relevant experience since completion of training. The outcome in Sweden in number of persons involved is shown in a table below.

The numbers presented below include for diagnostic radiology also those working in radiation protection and in MRI.

Application	All trained medical physicists	Mededical physicists with > 5y experience after completion of training
Radiotherapy	53	38
Diagnostic radiology	38	32
Nuclear medicine	44	37
Total	135	107
Total per 10^6 inhabitants	15.7	12.4

HOSPITAL PHYSICISTS DEPARTMENTS

All hospital physicists are at present employed in hospitals within the National Health Care system, and there are still virtually no private hospitals in Sweden. (Two private MRI installations do exist, in Stockholm and in Lund.) The administration of the hospitals is generally speaking based on 24 "län and landsting", administrative provinces with their county councils. Each province has at least one larger läns-hospital, central hospital, and a relevant number of smaller hospitals. On top of this are six health care regions, each with a larger regional hospital, including specialist clinical departments. The regional hospitals are generally also university hospitals, connected to basic education and training of medical doctors and hospital physicists. To be noted is, that the university hospitals are administrated by the county councils, while the universities are "connected" to the government.

There are of course big differences between different provinces, and 11 of the provinces have only one hospital physicist each. The very last province without a physicist actually created a hospital physicist's position earlier this year, 1994. Thus, there is at least one hospital physicist in each province today. Hospital physicists can be found in 30 hospitals in Sweden, and 13 hospitals are single physicist ones. The three largest hospital physics departments belong to the university hospitals in Gothenburg, Lund and Stockholm, all having 15-16 physicists each. The clinical departments at the university hospitals in Linköping, Malmö, Umeå and Uppsala are slightly smaller, with 7-9 physicists each. The remaining ten departments each have between 2-7 (average 4) physicists.

Number of qualified physicists at department	Number of departments	Total number of qualified physicists
1 (at central hospitals)	13	13
2 - 7 (at central hospitals)	10	42
7 - 9 (at univ. hospitals)	4	32
15 - 17 (at univ. hospitals)	3	48
Total	30	135

The hospital physics departments are generally organised as "clinics", on the same organisational level as clinical departments, with exceptions for some of the hospitals with single physicists. At the university hospitals, the professor in medical radiation physics is also head of the hospital physics department. It is also to be noted for the universities/university hospitals, that the physicists belonging to the university departments are not included in the numbers above; only the clinically working physicists, the hospital physicists, at the university hospital departments are counted.

As an example, eight physicists are working in the radiation therapy section of the hospital physics department at Lund university hospital. In full time equivalents they correspond to 6.5 physicists. In the external beam section there are 7 accelerators (3 with dual photon energies and a number of electron energies), 1 cobalt unit, 1 orthovoltage unit, 1 superficial unit, 2 simulators, 1 dedicated CT-scanner, 1 3D treatment planning systems with 3 workstations. In the brachytherapy section there are 2 remote afterloading units (1 LDR and 1 HDR), 1 simple simulator and 1 dedicated treatment planning system. There are also 2 computerised watertank dosimetry systems, TL, Fricke and ionisation chamber dosimetry systems. With a patient load per year of around 2000 new courses of treatment with external beam therapy and 150 with brachytherapy and a high degree of advanced treatments, the number of physicists ought to be around 9.5 whole time equivalents.

THEORETICAL EDUCATION AND TRAINING, M.Sc. and Ph.D. IN RADIATION PHYSICS

The population of Sweden is around 8.6 million; the number of hospital physicists per million inhabitants is thus rather high. One explanation might be the long tradition of physicists working in clinical radiation physics applications, another might be the strong connections between the clinical applications and the academic world. Radiation physics is a university discipline of its own with a total of seven professorships, and there are university departments of radiation physics at the universities in Lund - departments both in Lund (two chairs) and Malmö, Gothenburg, Stockholm, Umeå and Linköping. The professors of medical radiation physics belong to the medical faculty with only one exception.

Radiation physics is taught as one of several alternatives within the physics programme at the faculty of Natural Sciences at the universities in Lund, Gothenburg, Stockholm and Umeå (the latter at the institute of technology). The first two years of undergraduate education consist of mathematics and physics, computer science, mathematical statistics etc, common to a number of alternatives in the physics M.Sc programmes. The last two years of education are then dedicated to radiation physics, with half a year allotted to the M.Sc. thesis. The basic radiation physics education is harmonised in such a way, that the courses given at the different university departments largely cover the same knowledge material. The radiation physics syllabus covers atomic, nuclear and quantum physics, radiation sources, interaction between radiation and matter, detectors and methods of measurement, dosimetry, radiobiology, medical introduction, radiation protection, environmental radiology, nuclear medicine and systemic radiotherapy, diagnostic X-ray physics, radiotherapy physics including brachytherapy, applied dosimetry, imaging and non-ionising radiations including MR. The Lund syllabus is presented below:

M.Sc. in Radiation Physics: 160p = 4 years of academic education and training

year 1	**Basic physical sciences, 80p.**	**Requirements for RAF001: 80p, with > 30p mathematics, > 30p physics, 5p computer science + other relevant subjects**
year 2		
year 3	**RAF001, 0-40p**	**Basic radiation physics; req. for RAF002**
year 4	**RAF002, 41-80p**	**Applications in health care ...**

1p = 1 week of study

3years: B.Sc. Basis for medical radiation physics and for industrial work requiring knowledge of radiation physics.

4 years: M.Sc.Theoretical requirements for hospital physicist.

Requirement for post-graduate radiation physics studies - Ph.D.

Year 3: RAF001 - Radiation Physics 1-40p (Lund syllabus)

Introduction, Quantum mechanics 2p	**Atomic and nuclear physics, Radiation sources 7p**	**Interaction radiation - matter 6p**	**Radiation detectors methods of measurem. 5p**
Radiation dosimetry 10p	**Medical orientation 2p**	**Radiation biology 4p**	**Rad. protection - ionising and non-i. rad 4p**

1p = 1 week of study

Year 4: RAF002 - Radiation physics 41-80p (Lund syllabus)

Environment radiology 2p	**Tomographic methods, Imaging 2p**	**X-ray physics 3p**	**Nuclear magnetic resonance 2p**
Nuclear medicine physics 4p	**Radiotherapy physics 4p**	**Dosimetry in radiotherapy 3p**	**M.Sc. thesis 20p**

1p = 1 week of study

Further academic education and training to a Ph.D. level in radiation physics is arranged at all radiation physics departments. The Ph.D. programme covers four years, including approximately one and a half whole time year of theoretical studies and around two and a half years devoted to the thesis. A Ph.D degree is generally required for the higher positions as hospital physicist.

Ph.D. in Radiation Physics: M.Sc + 160p = M.Sc. + 4 years of academic education and training

Number of points	**Equivalent time**	**Type of education**
60p = 20p + 30p + 10p	**1.5 years**	**Theoretical courses**
100p	**2.5 years**	**Thesis**

The theoretical courses are divided into three groups. All post-graduate students have to take the two courses "Interaction between radiation and matter" (12p) and "Radiation dosimetry" (8p). Then there are optional courses which should cover 30p, to be chosen among advanced courses in the common subjects,

Medical Radiation Physics

medical radiation physics (X-ray, radiotherapy, treatment planning, nuclear medicine, ultrasound, MR, etc.), modern physics (e.g. quantum mechanics, solid state physics), electronics and computers, mathematical models and Monte Carlo methods, radiation ecology, radiation biology, medical orientation, imaging, radiation pharmacology, information theory and statistics... The last 10p are devoted to specialised courses connected to the subject of the thesis.

Clinically working hospital physicists are wellcome to participate in these post-graduate courses. There is also a Nordic collaboration around the post-graduate courses in dosimetry, interaction, radioecology and systemic radiation therapy, where teachers and research students from all Nordic countries have participated

LEGAL REQUIREMENTS TODAY

Hospital physics is not a regulated profession in Sweden. However, in 1989 the National Swedish Board of Health and Welfare issued a "General advice on competency requirements for hospital physicists", which replaced an older advice issued as early as 1958. An advice is of course never as strong as a regulation, but this advice is nevertheless of great importance for the profession.

The hospital physicist is "defined" in the introduction of the advice**: "To be able to use new and existing diagnostic and therapeutic methods and techniques in the fields of ionising and non-ionising radiation in a safe, rational and optimal way for patient, personnel and general public, collaboration with persons with competency in radiation physics, *hospital physicists*, is necessary."** The roles and responsibilities of the hospital physicist are then described in some length, as well as the development of the specialty with a presentation of the existing education and training. The requirements laid down on education, training and professional experience are in accordance with EFOMP recommenda-tions, in principle:

"when employing a hospital physicist, this person should have the full qualifications of a hospital physicist, consisting of

***	a university degree with a complete basic education in radiation physics from a department of radiation physics;**

***	clinical experience; a hospital physicist should during the first years of his/her clinical work be supervised by an experienced hospital physicist.**

Hospital physicists having management responsibilities should have several years of documented experience of clinical hospital physics tasks. Generally, these physicists also have a PhD in radiation physics or equivalent."

It is pointed out in the advice, that hospital physics is generally organised in independent departments and thus not subordinate to any other specialty. Further, it is mentioned that the responsible authority must plan carefully for the development of the field of hospital physics activities, as there is a limited access to physicists with appropriate clinical experience.

Even if the 1989 document is an advice and thus not compulsory, the advice has generally been accepted by the local authorities.

TRAINING AND EXPERIENCE

The Swedish advice on competence for a trained hospital physicist does follow the EFOMP recommendations in principle, by requiring not only theoretical university education but also clinical experience and on-the-job training. However, as there is no official training scheme for hospital physicists in Sweden, it is not possible to require clinical experience when first employing a physicist, according to the authorities; thus the formulation in the advice above concerning clinical experience.

Until some years ago, it was relatively easy for the new university graduates to find temporary positions at the larger hospital physics departments, thus getting the required clinical experience under the supervision of experienced hospital physicists. Even if the training was not provided as a formalised programme, in practice training posts were available. However, the situation is changing today with the much more restrained economic situation. In the newly introduced "buy-and-sell systems", all employees must be fully productive in the short term perspective. The long term perspective is regretfully disregarded (in spite of the advice above), and county councils tend to consider it outside their responsibility to provide organised on-the-job training for new physicists. The hospital physicists are a small group, on one hand with not too much power, but on the other it would not be too expensive to organise the clinical training for this small but necessary specialist group. All parties interested in promoting radiation physics in general and hospital physics in particular are collaborating in the organisation of relevant training schemes.

REGULATED PROFESSION?

For medical doctors there exists a training scheme, where the county councils are required to supply a certain number of paid training positions per year. This scheme is connected to the requirements a fully qualified medical doctor must fulfil in order to be allowed to practice medicine; a regulated profession. The situation might change to the better also for hospital physicists, as there are developments in the regulation area both in Sweden (see below) and on the European level in connection with the revision of the patient protection directive of the CEC.

In spring 1994, the government initiated a committee with the task to look into the qualification requirements of the professions in health care which are not yet regulated. Among the professions listed are hospital physicists. Just over ten years ago, there was another round of regulation discussions. The authorities then decided that it was unnecessary to regulate the profession of hospital physicists. One main argument was that hospital physics services were only required within hospitals, which all belonged to the national health service. As regulations were intended to protect patients and should be as few as possible, only those professions which could include private practices were regulated. The 1989 advice, described above, was a spin-off from those discussions. The situation today is different, with new privatisation trends in all areas of society; a private company selling hospital physics services could well be envisaged, for instance. EFOMP is now recommending guidelines on National Registration Schemes, and we are working along these lines in Sweden, at the same time as we are looking after our interests in the government committee.

Quoted from the EFOMP recommendations: "It is in the public interest, especially patients, that there should be an authoritative means of identifying those persons who have been recognised as competent to practice the application of physical sciences in health care."

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MEDICAL RADIATION PHYSICS EDUCATION IN SWITZERLAND

W. W. SEELENTAG [(1)]

STATUS

Medical physicists in Switzerland are organised in the "Swiss Society for Radiation Biology and Medical Physics" (SGSMP); many also have radiation protection responsibilities and will also be members of the "Fachverband", the German/Swiss Radiation Protection Association.

Some 30 medical physicists are employed in hospitals; 18 of them are certified with 16 working in radiation therapy: with a population of 7 mil. inhabitants this results in just over 2 experienced physicists in radiation therapy per mil.: a figure at the lower end of Europe with 1 ... 6.5 physicists/mil (EFOMP survey 1994). On the other hand there are 13 radiotherapy clinics, equipped with at least 1 linear accelerator (plus 2 under installation): roughly 1 clinic per 1/2 mil. inhabitants - many more centres than considered economically reasonable e.g. by WHO (recommends minimum 1 mil. inhabitants per centre). This is partly due to the fact that health care is to be organised by the counties - and there are 26 counties. So on average there are some 2 .... 2 1/2 physicists per centre: few centres employing several physicists and many clinics with just one single physicist. Other fields of medical radiation physics (nuclear medicine and diagnostic radiology) will usually be covered "part time" by the radiotherapy physicists.

There are also several research institutions employing medical physicists, e.g. the Institute of Applied Radiation Physics (Lausanne), and the Paul-Scherrer-Institute (Villingen, working e.g. on pion and proton therapy).

The combination of low numbers of medical physics positions (relative to the population), and a small country like Switzerland, hampers the establishment of formal, university based training courses. There is no formal graduate training in medical physics; prospective medical physicists will get their degree in physics in general; there are limited possibilities to do the diploma work in medical physics. This winter (1994/95) a first postgraduate teaching course will be held at the Technical University (ETH) Zurich, organised by the Institute for Biomedical Engineering in close co-operation with SGSMP.

Historical development: In 1980 the (then) new legislation regulating the use of accelerators for radiotherapy came into force; this made it mandatory to employ a "suitably qualified physicist". In order to help to identify "suitable qualification" the SGSMP set up in 1987 a voluntary certification scheme (the "Fachanerkennung") for "Medical Radiation Physics"; in 1988 15 physicists with long experience were awarded the certificate within a transitional regulation. In 1991 an agreement was reached with the "Swiss Society for Medical Radiology" to actively support this scheme; at the same time the subject was extended to "Medical Physics"in general, with the possibility to name a field of specialisation: as Swiss medical physicists are still predominantly engaged in radiotherapy, "Medical Radiation Physics" is the only specialty which has been certified so far. The importance of this certification has been considerably advanced by the new (1994) radiation protection legislation: a physicist is now required for other radiotherapy procedures as well, and the "Fachanerkennung SGSMP" is demanded explicitly - a big step towards state recognition.

THE "FACHANERKENNUNG"

Aims:

The candidate has to have sufficient theoretical knowledge and practical experience to work independently in the fields of

- clinical aspects of medical physics
- application of ionising and non-ionising radiation, considering the basic radiobiology
- dosimetry
- radiation protection
- instrumentation
- equipment evaluation and quality assurance

Prerequisites and procedure;

- a university degree (at least M.Sc) in physics or a related subject
- 3 years of practical education and training in a hospital
- lectures on medical subjects, which may be replaced by study of the literature for applicants not working at a university hospital
    - anatomy
    - physiology
    - medical radiology
    - radiobiology
    - one more medical speciality to be chosen by applicant.

- guidance by a supervisor (with Fachanerkennung), who should preferably work at the same institution as the applicant, and who has to write a yearly report on the applicant's progress

- radiation protection course (at least two weeks)
- attendance of at least 4 scientific conferences
- at least 1 publication
- written and oral exams by a commission, consisting of:
  - 4 representatives of the Society of Radiobiology and Medical Physics, usually:
  - 1 radiation biologist
  - 1 radiation protection expert (usually also representing the regulatory authority)
  - 2 radiologists, representing the Society of Medical Radiology.

Results to date:

- 4 certifications according to this procedure, i.e. outside the transitional regulation
- 22 practising medical physicists are certified (some with foreign training were considered equivalent, some retired)
- 7 candidates enrolled in his scheme (see below for additional candidates with postgraduate course at ETH)

POST-GRADUATE TEACHING AT ETH ZURICH

Since 1991 a lecture on "Medical Physics" (2 terms) has been offered at the Institute of Biomedical Engineering at the Federal Technical University (ETH) Zurich. This lecture has now been incorporated into a postgraduate training course, beginning winter 1994/95. The course is designed to contain all theoretical studies required for the "Fachanerkennung" and at the same time offers several wider options for students not aiming at the "Fachanerkennung". The lectures are complemented by practical block courses during vacations.

Syllabus first year (basic studies): all students

	Biomedical technology I
	Biostatistics
	Radiation biology
Block course	Computers in medicine
Summer (lectures):	Biomedical technology II
	Medical optics
	Physiology

Block course: Biomedical procedures

Syllabus second year (specialised): students aiming at "Fachanerkennung"

Winter (lectures):	Clinical medicine II
	Medical acoustics
	Medical physics I
Block courses	Dosimetry
	Radiation protection advisor
Summer (lectures)	Clinical medicine II
	Medical physics II
	"practical medical physics" (*)
Thesis	Possible subjects to be decided

(*) This lecture is to be given by several medical physicists from different hospitals with two main aims:-

- to give students a chance to get in contact with practising medical physicists: as most positions for medical physicists will be available in non-university clinics, this is considered especially useful.

- to cover fields of medical physics routine not fitting well into the main medical physics lecture.

Other possible specialities for the second year could be e.g. biomechanics, biophysics, or medical engineering.

All students are urged to attend also other lecture of interest (e.g. medical informatics, radiology, oncology) offered at Zurich University Hospital: this will be co-ordinated for each individual student by a tutor.
26 students have enrolled for this first course, including 20 physicists; 8 of these are aiming at the "Fachanerkennung".

FURTHER SGSMP ACTIVITIES

SGSMP organises annual scientific congresses, on several occasions in co-operation with the Austrian and/or German Medical Physics Societies, or the Swiss Society for Biomedical Engineering. These conferences will often also offer tutorials. The papers presented are published as proceedings.

Roughly once a year symposia (lasting 1 or 2 days) on areas of special interest (e.g. planning systems, magnetic resonance procedures, predictive assays) are organised.

Medical Radiation Physics

There are working groups on specialised subjects, either to foster co-operation, or to draft recommendations (e.g. on dosimetry, or quality assurance in all aspects of radiological physics).

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MEDICAL PHYSICS TRAINING - HISTORY AND DEVELOPMENTS IN TURKEY

G. KEMIKLER(1), I. OZBAY(1), S. KUTER(1)

HISTORY

The history of Medical Physics in Turkey goes back to 1935, when the German Biophysicist Prof. Dr. Friedrich Dessaner was appointed as Director to the Radiology and Biophysics Institute, Faculty of Medicine, University of Istanbul. Medical Physics as a profession in Turkey was initiated in the same department in 1953, when the possibility of employment was created. In 1986, formal postgraduate training and education in the field of Medical Radio-physics was initiated by the Oncology Institute of Istanbul University.

THE PRESENT STATUS OF MEDICAL PHYSICS IN TURKEY

Medical Physics generally stresses on radiation oncology physics in Turkey. The medical physics profession primarily involves the application of physics in diagnostic and therapeutic radiology and includes responsibilities directly relating to patient care. Due to the large and growing demand for Medical Physicists in our country, candidates start to work without sufficient background in physics and medically related subjects. Less than half of the physicists begin their careers in Medical Physics after going through education and training in required area(s).

In our country, medical physicists work in different medical fields. Most of them are working with ionizing radiation, few of them with non-ionizing radiation. There are approximately 150 medical physicists employed in different medical fields (Table 1).

The majority of medical physicists are at present employed in Radiation Oncology departments within the university or public hospitals.

In Turkey, the medical physics units or medical radiophysics departments are sections of radiation oncology departments of public hospitals, or medical faculties. They are organised and managed by the director of the clinic, the head of the department or the chief physicist . The M.Sc. and Ph.D. in Medical Physics is a multi-disciplinary course administered by the Department of Radiophysics and taught by the Institute of Oncology and a number of departments at the University of Istanbul.

Turkey

TABLE 1: Fields where medical physicists are currently working in Turkey

Number of Physicists	Percentage	Working Areas
60	41%	Radiation Oncology
36	24%	Radiation Protection and Safety
16	11%	Nuclear Medicine
7	5%	Diagnostic Radiology
Total 121	81%	WITH IONISING RADIATION
19	13%	Biophysics and Biology
10	6%	Other Disciplines
Total 29	19%	WITH NON-IONISING RADIATION
150	100%	TOTALLY

POST-GRADUATE EDUCATION AND TRAINING IN MEDICAL RADIOPHYSICS

In Turkey specialisation education on Medical Radiophysics is not available, due to the fact that Medical Radiophysics is not accepted as a specialisation. The Medical Radiophysics unit included in the Radiotherapy Department has been unique school for radiophysicists and almost all of the radiophysicists in our country have been educated here through long-term postgraduate courses. Since it has not been possible to do the required amount of clinical practise, this unit has not been able to give the desired level of practical training. Special courses and summer schools have only served the purpose of refreshing knowledge. After the institute of Oncology has been established in 1986, the academic education on Medical Radiophysics began M.Sc. education on Medical Physics also began in the Oncology Institute of Hacettepe University in Ankara in 1993. These education programmes have been prepared according to recommendations of international federations.

POSTGRADUATE EDUCATION

a) Up to 1986, there was no formal grading criteria of Medical Physics in Turkey. The first postgraduate programme was started by The Institute and Clinic of Radiology, Faculty of Medicine, University of Istanbul. Postgraduate education of young medical radiation physicists was carried out on the Radiation Physics Department. It was the largest and most acknowledged centre in Turkey. We used to organise basic and advanced postgraduate medical radiation physics courses and give training and practise to there physicists and physicians who entered the radiological fields. The training courses had been organised every now and then by our Medical Radiation Unit and continued until 1986.

b) The postgraduate Education and Training in Medical Physics initiated formally at The Oncology Institute of the University of Istanbul in 1986. The Medical Radiophysics Department of a scientific discipline in the Basic Oncology main branch The Medical Radiophysics Division of Oncology Institute of Istanbul University has been seven medical physicists, two of whom are in academical position. Our department is responsible for the treatment planning of over 3 thousand new patients per year. The institute has several treatment machines, a 18 MV linear accelerator Saturn (electron 6, 9, 13, 15, 17 and 20 MeV), 2 Co-60 units, 2 superficial Xray machines, one ortho-voltage X-ray machine, one high dose Curieton remote afterloading system with Co 60 source, manual low dose-rate brachytherapy with Ir-192 wire, two simulators and Theraplan, treatment planning system, water phantom system and dose measurement systems. The Medical Radiophysics division of the Oncology institute offers two post-graduate programmes. The aim of postgraduate education is to acquire an adequate academic knowledge of the application of physical science to medicine.

1: Master of Science Degree (MSc.) Program: This is postgraduate education and training after BSc. degree. It takes at least two years and includes a formal curriculum of lectures, seminars and practical training. Thesis study and practical training are carried out in second year. While in the first year the trainee is given a background in all the required fields. The first term lasts from October till February and second term - from March till mid-June. The curriculum topics are listed on table 2, below.

The trainee must pass all of the topics. On-the-job training for practical experience involves practical exercises and routine work in the hospital. Trainees work in their theses in the second year. The trainee, then, takes an oral exam prepared by an examiners team including medical physics and radiation oncology experts and is awarded a M. Sc. Diploma.

Medical Radiation Physics

Table 2. Master of Science of Degree (M.Sc.) Educational programme. Name of the topics.

1st Year First Term	1st Year Second Term
General Radiation Physics	Medical Radiation Physics
Basic Radio-Biology	Medical Radio-Biology
Clinical Oncology 1.	Clinical Oncology 1.
Anatomy Histology and Pathology 1.	Anatomy, Histology and Pathology 1.
Biostatistics	Seminar
Computer Techniques and Procedures	
*Bio-physics	
*Medical Biology and Genetic	
*General Epidemiology	
*Elective topics	

2: Doctorate Degree (PhD.) Program: This is higher level postgraduate education and training after completion of MSc. Degree Program. It takes at least three years. The trainee is to take specified courses in the first two years. These two years also, include practical training that is done under the supervision of a qualified medical radiation physicist. In the third and forth years, trainees work on their theses. 2-3 years of practical experience in a hospital helps the physicists to work with confidence in the clinical atmosphere. Usually, a number of medical physicists work for and complete Ph.D. programmes while in service. These candidates are assessed by written exam and then oral exam, and if successful, work on their thesis. The curricula of doctorate degree education are given in table 3, below:

Table 3. Doctorate Degree (Ph.D.) Educational Programme Name of Topics

Ph.D. Education I. Year	Ph.D. Education II. Year
Photon Dosimetry	Brachytherapy Dosimetry
Electron Dosimetry	Medical Imaging Systems
Clinical Oncology II	Medical Radio Biology

Turkey

Anatomy, Histology and Pathology II.
Quality assurance in TR.
* Cancer epidemiology
* Medical biology and cancer genetics
* Elective topics
Radiation protection and safety
Treatment planning
Seminar

GENERAL OUTLOOK OF SYLLABUS

General Radiation Physics: Atomic and nuclear structure, radioactive decay, decay of modes, natural and artificial radioactivity, interactions of X-and gamma rays, production of X-rays, physical principles of diagnostic radiology, dose units, primer and secondary ionization chambers, methods of measurements, measurement of radiation quality and exposure.

Medical Radiation Physics: Low, medium and high treatment machines, sources and machines in brachytherapy, radiation dosimetry for X-rays and electron beams, measurements of absorbed dose, physical principles of radiotherapy, dose-volume concepts, immobilisation devices, dose distributions in external beam therapy, dosimetric variables, inhomogeneity, systems used in brachytherapy, dose time-fractionation relations in RT, radio protection and quality control in RT.

Photon Dosimetry: Absorbed dose protocols, radiation quantities and units, equipments, radiation quality specification and determination, formalism, determination of absorbed dose to water, correction factors, conversion of absorbed dose from one medium to another, quality control for absorbed dose and inter comparison.

Electron Dosimetry: Electron accelerating structures, beam bending systems, flattening of beam, electron interactions with matter, energy losses, basic parameters of electron beams, beam distribution in the patient, practical electron dosimetry, dosimetry methods and algorithms.

Brachytherapy Dosimetry: Sealed-sources therapy, radionuclides and sources application methods of brachytherapy, specification of sources, standardisation of source-dose-volume, dose calculation methods - intracavitary and interstitial -Paris system, Quimby system, Manchester system, Stockholm system, Houston system, source reconstruction methods and time dose-fractionation in brachytherapy.

Treatment Planning: Pre-treatment procedures, principles of external beam treatment planning, isodose charts. parameters of isodose curves, wedge filters, tumor-dose specifications, acquisition of patient data, irregularities inhomogenities, field shaping adjacent fields and practical treatment planning.

Medical Imaging Systems: Standard roentgen units, tomography and computerises tomography units, ultrasonography, emission type imaging units, gamma cameras, positron emission tomography and physical principles, principles of magnetic resonant imaging, current concepts and issues in radiation protection and quality control of imaging systems.

Radiation Protection and Safety: protection quantities and units, risk-benefits-analysis, biological effects of radiation risk factors and side limits, dose calculation of in and out irradiation, shielding, legislation, administration and organisation and licensing regulations.

Basic Radiobiology: Absorption of X-rays, neutron and heavy ions, cell-survival cures, RBE, LET, oxygen effect, dose response relationships for normal tissues, lethal and sub-lethal radiation damage, radiosensitizers, radioprotectors, acute effects of whole body irradiation, genetic changes.

Clinical Radiobiology: The physics and chemistry of radiation, absorption, cell-survival curves, dose response relationships for normal tissues, radio sensitivity, radiation damage and dose-rate effect, cell-tissue and tumor kinetics, time-dose fractionation in radiotherapy, sensitivity of tissues, late effect of radiation.

Anatomy-Histology-Pathology: Anatomy and histology of skin, musculo-skeletal, respiratory, digestives, cardiovascular, urinary reproductive, endocrine, haematopoietic and nervous system, origins of disease and disability, review of the pathology of cancer, pathological classification of organs, modes and sides of metastases.

Clinical Oncology: Malignancies of organs and systems, etiology. staging of tumors, treatment modalities, surgery RT and chemotherapy and side RT schemes

Medical Biology: Cell, tissues and organs DNA, RNA, mitosis, meiosis, differentiation, genetics, effect of radiation cell degeneration.

Computer Techniques and Procedures: Basic concepts, programming, personal computers, high and low level languages, formatting floppy discs, back up electronic data and operating systems.

Biostatics: Data recording, graphical and parametric presentation, probability, tests of significance, binomial, Poisson and Gaussian probability distributions, sampling theory, and design of experiments.

Educational programmes have been organised according to the recommendations of international organisations like EFOMP, AAPM, IAEA and IOMP. Up till now, 25 physicists have received a Masters Degree diploma and 5 have received a doctorate degree diploma. Currently, over 15 physicists are either in training or are working in their theses. More than 30 physicists, who have completed their training are working in radiation oncology departments spread over the country.

Turkey

The population of Turkey is around 60 million. The number of Medical Physicists per million inhabitants is very low, only one physicist. There are 21 departments in public or university hospital and 7 private centres. The distribution of the treatment machines and status of RT. departments is shown Table 4.

Table 4. The Distribution of the Treatment and Status of RT. departments.

Status	Number	Linac	Co-60	Orthov	Superfic	Brachyth.	Brachyth
Public or Univ. Hospitals	21	12	30	10	9	16	
Private Centres	7	--	8	1	2	--	
TOTAL	28	12	38	11	11	16	

In table 5 the number of medical physicists in Turkey with various educational qualification is shown.

CONCLUSION

In conclusion, the structure and organisation of Medical Radiation Physics (Radiation Oncology Physics only) are formally approved and fairly advanced in Turkey. Diagnostic Radiology, Nuclear Medicine and non-ionising radiation. postgraduate programmes have not been initiated formally. However, there is increasing demand for these programmes. Every year, about 4-6 M. Sc. and 2-4 Ph.D. students are admitted for postgraduate education and training. Foreigners are acceptable. The training scheme and status of the clinical medical physicists are broadly in agreement with the EFOMP policy statements.

Table 5. Educational qualification of Medical Physicists in Radiotherapy.

Degree	Working areas	No. of Medical Physicists
B.Sc.	Radiotherapy Dep.	32
M.Sc.	"	25
Ph.D	"	5

Medical Radiation Physics

A medical physicist has to make some decisions about the patients and such decisions are based on a competence that only the discipline of Medical Physics covers. These facts have to be taken into account within the organisation and management of the Medical Physics Service. After the basic qualification (B.Sc.) further education and training in Medical Radiation Physics is essential before a medical physicist is allowed to take responsibility.

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THE HISTORY, ACHIEVEMENTS AND PROBLEMS OF UKRAINIAN MEDICAL RADIATION PHYSICS AND ENGINEERING

V. E. OREL[(1)]

HISTORY

In 1920 the specialists in medical physics Yu.P.Teslenko and E.E.Trotsky organised departments of medical physics and engineering at the Kiev Roentgen Institute. On this occasion, one of the Kiev newspapers published an articled called "A House of Mysterious Rays". From 1923 through to 1933, the department was headed by professor V.K.Roche. The major issues facing physicists and engineers at the time were to develop metrology and x-ray standards. The scientific seminars held by the department were attended by would-be Nobel Prize winners N.N. Semonov and I.E. Tamm. During 1933 through to 1939 when the Department was headed by Professor I.V. Domansky medical physicists were studying X-ray radiation on photographic film in order to enable Quality diagnosis of cancer patients. An interesting approach for using ionizing radiation in medical jurisdiction expertise was developed by B.R. Kirichinnsky who headed the department in 1940-1941 and 1946-1948. In the pre-war years, the biologic effects of ultra-high frequency were studied by Yu. A. Sikorsky, brother of a well-known helicopter designer of Ukrainian descent. During 1948-1973, headed by M.S. Ovoshnikov, the department organised an engineering office, an experimental production unit and a dosimetry laboratory. This unit dealt with developing original X-ray equipment: fluorographic equipment and instruments for filming humans full-length at a reduced scale. In 1974-1991, the department headed by B.J. Nikishin was engaged in implementing the ideas of using neutron and gamma irradiations for treating cancer patients. They developed a model of a fourth generation X-ray computer tomograph.

An outstanding achievement of the Ukrainian scientists is the development of the theoretical basis of the X-ray Computed Tomography as early as 1957. This fact has been discovered occasionally some 10 years ago and after we were informed for it by Dr S.D.Tabakov a copy of this historical paper was discovered in the Polytechnic Institute of Kiev (S.I.Tetelbaum, About a method for obtaining volume-images using X-rays, News of the Polytechnic Institute of Kiev, v.22, 1957), the mathematical base had been worked out by B.I.Korenblyum. Although these papers had been published several years before the well-known Nobel prise winning papers, they have not been seen from the scientific world and now it is not known even if a working model has been built.

Medical Radiation Physics

STATUS AND RESEARCH

Since 1991, the physico-technical department has been headed by the author of this article. The work is carried out in the basic fields of medical physics and applied medical radiation engineering. As to the basics we study the dynamics of change in the spectral features of mechanically stimulated electromagnetic emission from blood, i.e. mechanoemmision under the influence of ionizing radiation. We have demonstrated a relation between mechanically stimulated electromagnetic blood emission in optical and radio ranges and absorbed doses of ionizing radiation. Studies were also carried out on cellular organelles, i.e. mitochondria and DNA. These experimental investigations served as the basis for mechanoemission hypothesis for chains of developing oncologic lesions as one possible mechanism of radiation induced carcinogenesis. The technical implementation of the physical principles of mechanoemissions was used for creating an instrument, a mechanoemmision analyzer, designed for the study of the spectral composition of blood mechanoemission from cancer patients for differential diagnosis and control during radiotherapy, as well as a biological indication of human radiation injury. A problem for medical physics is posed by methodologic features of radiotherapy for deeply seated human tumours. One of the promising approaches for the solution of this problem can be a synergic effect of ionizing radiation and hyperthermia. To solve this problem we developed an original installation of inductive ultra high frequency treatment for cancer patients in combination with radiotherapy. (For more information on these subjects please see the references).

A vast amount of work was done by Ukrainian medical physicists in physical dosimetry and biological indication of victims and the environment after the Chernobyl nuclear power station accident in 1986. In this connection a Ukrainian Centre of Radiation Medicine was founded in Kiev. One should mention the work of medical physicists and engineers from Kharkiv Institute of Radiology who carried out fruitful investigations in the field of clinical and individual dosimetry of ionizing radiations.

In recent years Ukraine has been producing X-ray computer tomographs at the Relay and Automatics plant in compliance with Siemens technical recommendations. Some parts of X-ray diagnostic and radiological therapeutic instruments are developed and manufactured by the Medapparatura company in Kiev. The institute of Nuclear Investigations developed a medicobiologic complex for neutron treatment of cancer patients. An X-ray emitter is being developed by the Saturn company.

REPRESENTING BODY AND EDUCATION

In 1993 the Ukrainian Association of Medical Physicists was founded which publishes a journal "Physics of the Alive". The number of physicists and engineers working in Ukrainian cancer hospitals approaches 200. The number of specialists engaged in engineering and the medical radiation physics in Ukraine as a whole is about 1000.

In May 1995 a Ukrainian Radiological Congress will be held in Kiev with international participation at which a section of medical physics and engineering will work.

The Kharkiv College of Radioelectronics is training students for servicing radiological equipment. Specialists in radiation medical physics and engineering are trained at the Department of Medical Engineering of the International Solomon University in Kiev. Post Graduate courses can be completed in Kiev and Kharkiv.

PROBLEMS

Despite the glorious history and certain advances, Ukrainian medical radiation engineering and physics have certain problems today. These are primarily:

1. Absence of a unique system of metrology and standard of ionizing radiation with Europe;
2. A limited number of modern instruments, computers and programs for clinical and individual dosimetry;
3. Lack of possibilities for training at leading European centres for specialists in radiation physics and dosimetry;
4. Lack of modern textbooks in radiation physics and engineering for students
5. Lack of funds for purchasing medical, physical, and bioengineering journals.

One might hope that under the new conditions of a new Europe these problems could be solved and we might hope for the support of European specialists in Medical Radiation Physics and Engineering. In this context we would like to express our acknowledgements to the organisers of this Conference.

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TRAINING FOR PHYSICAL SCIENTISTS IN HEALTH CARE - UK SCHEME

S.B.SHERRIFF(1)

The Institute of Physical Sciences in Medicine, with a total membership of 1717, is the United Kingdoms professional body for physicists and engineers with an interest in health care. The scope of the work is manifold encompassing not only the traditional areas of radiation physics and imaging but also topics such as rehabilitation engineering, instrument design and physiological measurement. 1154 of the members work directly in the UK health care sector in either National Health Service Hospitals or University Medical Schools. These 1154 are spread throughout approximately 125 departments of varying size spanning the length and breadth of the United Kingdom from Inverness to Plymouth and Norwich to Belfast. The breakdown of staff by departmental size, and by discipline are given in Tables 1 and 2 respectively.

Table 1.

No of Departments	No. of staff in Department
67	< 5
32	5 - 14
16	15 - 30
8	> 30
Total 125	1154

Table 2.

Field of Medical Physics	No. of staff
Radiotherapy	252
Radiation Protection	145
Non-Ionising Radiation	24
Diagnostic Radiology	103
Nuclear Magn. Resonance	32
Nuclear Medicine	193
Ultrasonics	58
Other	347
Total	1154

Table 1 shows the number of Medical Physics Departments in the UK grouped according to the number of graduate scientists in each department.

Table 2 shows the various fields of Medical Physics together with the number of graduate scientists who have declared that to be their main area of activity.

Medical Radiation Physics

The diverse range of modern Medical Physics and Biomedical Engineering and the evolution of identifiable sub-disciplines within the field require that there is a formal approach to the training of new entrants to the profession so that a proper vocational foundation to their careers is ensured. The Board of directors of the Institute of Physical Sciences in Medicine appointed a Training and Education Committee to both devise and administer a suitable Training Scheme.

The first official Training Scheme was set up in 1981 in response to the need for a more formalised training programme. At that time, the majority of persons entering the scheme were employed as basic grade physicists. Many of them were required to combine their training with the exercise of routine duties and the scheme was devised to take this into account. In 1990 following a fairly fundamental change in the way physicist's posts in the NHS are funded the concept of supernumerary posts for trainee medical physicists was introduced. This gave us an opportunity to review training methods, to look again at both how training should be provided and what training should be provided. The current scheme, which has an annual intake of around 32, was devised with the purpose of producing highly competent medical physicists and biomedical engineers by providing new entrants to the profession with a structured programme of education, training and experience enabling them to progress to Corporate Membership of the Institute and entry to the appropriate Practice Register.

The requirement for Registration of both the medical physicist and the chartered engineer consists of three elements; knowledge base, training and experience. The Training Scheme attempts to provide for all three facets of registration.

KNOWLEDGE BASE:

The trainee obtains the necessary knowledge component of training from an accredited MSc. The IPSM, as the professional body setting the standards for the Training Scheme as a whole, has responsibility for accrediting MSc courses. The accreditation process includes: a review of the Syllabus and Curriculum to assess the coverage by the course of the knowledge content specified in the IPSM syllabus; a site visit; the examination and assessment process; the project and dissertation work, etc. It is not however an audit of the academic worth of a MSc. This is entirely the responsibility of the University involved. A suitable knowledge base is defined in the IPSM syllabus as one which provides a satisfactory balance between, (i) a breadth of topics giving a trainee an adequate overall view of the subject and (ii) a study in sufficient depth of a limited range of topics expected to equip the trainee with the knowledge to underpin practical training and future work in a narrower set of selected areas and eventually in a particular speciality.

The syllabus sets out Prescribed topics, Core topics and In-depth topics. The Prescribed topics, which are set out in some detail, consist of anatomy and physiology, and safety. The core topics, defined as those which contain material which may be required in more than one specialist area, include: Computing; Statistical Methods; Equipment Management; Quality Management; Introductory Signal Processing, Ionising Radiation Physics; Non-Ionising radiations; Imaging; and Medical Electronics. Each In-depth topic is intended to provide essentially complete coverage of a particular specialist area when taken in conjunction with the relevant core topic material. The In-depth topics listed are: Anaesthesia and Respiration Therapy; Audiology; Biomedical Engineering; Computing and Medical Informatics; Diagnostic X-ray Physics; Imaging; Image and Signal Processing; Magnetic Resonance; Medical Electronics and Instrumentation; Non-ionising Radiation; Nuclear Medicine; Ophthalmology; Physiological Measurement; Radiation Protection; Radiotherapy Physics; Rehabilitation Engineering; and Ultrasound.

TRAINING

Candidates are only accepted onto the Training Scheme if they are based in an accredited training centre. Just as in the case of the MSc courses the IPSM, as the professional body setting the standards for the Training Scheme, has responsibility for accrediting training centres. The accreditation process involves a site visit by two surveyors and includes a review of: subject areas available for training; staffing levels; facilities such as library, study room, computers, and meeting programmes; training organisation; research output; and continuing professional development programmes. A total of 30 centres have received accreditation and approval to take Trainees.

The *total* Training Period is based on a broad developmental progression of competencies, leading towards increased specialisation during the experience period. It is divided into two parts: two years basic training as a supernumerary trainee (Grade A) and at least two years experience/higher training in a substantive full time medical physics post (Grade B). The Prospectus has been written with reference to Competency Levels. Emphasis is placed primarily on continuous assessment by the supervisors in the recognised training centres. The trained medical physicist should be capable of undertaking a given job of work in any medical physics and biomedical engineering department, in the UK or abroad.

When assessing competencies against the markers provided, it is deemed important to test the qualities normally associated with a professional physicist or engineer. These include demonstrable problem solving skills, including the ability to define a problem and formulate strategies for solving it, the ability to interpret novel or non-standard data, the ability to make value judgements in unfamiliar situations, the ability to communicate scientific advice clearly and accurately to others, the ability to recognise fault situations, e.g. inappropriate images, and take suitable corrective action, also an appreciation of the limitation of one's knowledge.

Three levels of competence (A,B,C) have been described in the Training Scheme Prospectus, these are interpreted in a table below.

The three levels of competence described are currently available in ten major subject areas: Computer Science; Diagnostic Radiology; Electronics and Instrument Design; Non-Ionising Radiation; Nuclear Medicine; Physiological Measurement; Radiotherapy Physics; Rehabilitation Engineering and Ultrasound. We hope to provide these levels of competence in more subject areas and to extend the competency levels to higher levels, D, E, etc. in order to cover mature continued professional development.

The two year supernumerary training period in Grade A, has an emphasis on acquisition of knowledge and basic training. It includes training to competence level B in three major subject areas and in the Core competencies common to all areas (e.g. safety; interpersonal skills; scientific method), training to level A, acquaintenceship, in at least three additional subject areas, and the maintenance of a training portfolio. Throughout this training period the trainee has regular meetings with his/her supervisor and training co-ordinator.

United Kingdom

Level	Interpretation
A	**Acquaintanceship**: Experience gained during a brief period spent within a subject area.
B	**Basic**: Adequate span of theoretical knowledge to current state of the art: ability to apply this knowledge with reasonable skill, under supervision; ability to explain problems to other specialists and discuss response, with appropriate vocabulary.
C	**Corporate**: Higher training/experience leading to an adequate span of theoretical knowledge; ability to perform given or routine professional tasks without supervision; demonstrable problem solving skills; ability to recognise fault situations; demonstrable capacity for interpreting the state of the art to non-specialist clients, professionals in related disciplines, students, enforcing authorities or administrators.

Once the trainee has satisfied the supervisors and training co-ordinator that s/he has achieved the necessary competencies in the continuous assessment they may proceed to the *viva voce* examination. This takes approximately one hour and is conducted by a panel of examiners, each one a specialist in a specific area of medical physics and, drawn from senior members of the profession. The examination comprises an in-depth examination of the core competencies and three major subject areas, a superficial examination of other areas with which the trainee is expected to have an acquaintanceship, and questions on health and safety. Following a successful *viva voce* examination the Examiners evaluate the supervisor's and training co-ordinator's reports and the trainee's portfolio before determining the overall grade of the trainee. An award of the Postgraduate Dip IPSM is made to successful candidates and the trainee becomes eligible for a substantive, Grade B, post.

EXPERIENCE/HIGHER TRAINING

During a further training period consisting of a minimum of two years whole-time equivalent in a substantive Grade B post the progressive development of competence continues, but with the greater degree of specialisation and the deeper understanding that is expected of such a post. For satisfactory completion of the higher training period it is necessary to demonstrate competence to level C in one major subject area plus proficiency in relevant topics in related subject areas. The trainee must maintain a training portfolio in order to provide evidence of the depth and to a lesser extent the breadth of experience acquired.

The end-point assessment of competence, which may be taken after a minimum of two years in higher training, is in the form of an oral examination at the trainees place of work. During a period of approximately two hours the higher trainee is invited to demonstrate and discuss his/her work with two External Assessors both of whom are senior experts in the specialist field. Satisfactory completion of the assessment entitles the candidate to be entered on the Register of Scientists in Health Care and to become a Corporate member of the IPSM.

CONTINUING PROFESSIONAL DEVELOPMENT

Individual medical physicists have always recognised that education and training does not stop on reaching registration status but that it is a continuum from entry to university to retirement from the profession. It is not sufficient to rely solely on the knowledge gained during pre-registration training if patients are to be provided with a high standard of care for the ensuing 20/30 years of a members working life. Continuing professional development, which ensures the acquisition and dissemination of knowledge and skills, takes place informally, for example, by the reading and writing of scientific articles, the preparation of teaching material for undergraduate and postgraduate students, continuing research, participation in scientific meetings and attendance on courses and conferences. In the United Kingdom this is partially facilitated by the IPSM via the publication of journals, books and reports on Medical Physics and by the provision of a full programme of scientific meetings, with topics ranging from 'Quality Assurance and Patient Dosimetry in Diagnostic Radiology' to 'Engineering and Technology in the Management of Diabetes' and from 'Computer Aided Diagnosis in Nuclear Medicine' to 'Biomechanics in Sports Rehabilitation'.

To date the only group where a semi-formalised programme of CPD operates is for those members working as Radiation Protection Advisers. The comprehensive training for such a person takes place post registration and a set of competencies, at level D/E, has been devised based on nine major units as follows: supporting risk control; updating radiation safety policies; assessing risk; establishing radiation controls; monitoring of controls; cultivating safety awareness; legislation compliance; training of staff; contributing to advances in safety. The certification of RPA's is the responsibility of the IPSM; any prospective adviser has to satisfy the Institute that they are competent in the areas specified above before being issued with a five year certificate. To renew the certificate an applicant must be able to show that they are currently active in the field and that they have attended a number of 'update' meetings during the preceding five years. A programme of update meetings is organised at regular intervals by the Institute.

The IPSM is in the preliminary stages of designing formal post registration education programmes and is looking towards requiring evidence of satisfactory participation in CPD for those members wishing to be involved in the education, assessment and examination of their various disciplines. There are many questions still to be answered. What should be the basic unit of activity? How many units should be the target? How long should the time cycle be 3 years 5 years? Is a mix of home and away training the most appropriate? How will the need for protected time and funding for CPD be obtained, etc.? Nevertheless given the rate at which medical physics is advancing, the complexity of many of the issues and the increasing public expectation in the provision of health care it is essential that CPD becomes more structured.

In the final event the success or failure of any training programme is dependent not just upon the endeavours of the Institute or Organisation, but upon all the members of the profession.

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DISCUSSIONS

The Discussion on Education, Training and Accreditation began after the presentations of the participating countries. Various questions for this discussion were prepared during the distant pre-Conference discussion, when the Policy Statements of EFOMP were distributed to the delegates.

EDUCATION

The discussion began with specifying the level of the post-graduate education. Considerable differences were found. Almost all Central/Eastern European (EE) countries and some EC countries considered post-graduate education as education after the MSc (~5 years of academic education). As in those countries the MSc equivalent degree (Diploma, etc) is regarded as entry requirements for post-graduate education, the post-graduate students receive an official certificate after completing the course. This certificate is very important for career and PhD development, but is not considered as an academic degree. In many of the EE countries there exist specialised educational institutions, which deal with the post-graduate education of medical doctors. These are normally one per country and the Medical Radiation Physics (MRP) post-graduate courses are often incorporated within their activities. Only recently some Universities have introduced post-graduate education with MSc degrees in MRP.

In many Western European (WE) countries the entry requirement for post-graduate education is B.SC (~3 years of academic education) and completion of the course leads to MSc degree. These major differences are of the competence of the Higher educational Authorities and the Universities of the countries.

Special attention was given to the fact that the post-graduate education in MRP should also cover some engineering aspects, as the complex modern medical equipment can not be studied as a "black box" only. There are many engineers in X-ray, nuclear, imaging, etc. fields which are to be considered as medical radiation physicists. In EE these specialists are members of the national professional societies and through them - to EFOMP and IFMBE. In many countries the physicists and the engineers have formed merged societies and have equal status. It was agreed that the most appropriate length for post-graduate education is one academic year.

At this point it was agreed that revealing the weaknesses and strengths of the existing education schemes will be of importance for the development of proper strategy in post-graduate education. **Table 1** shows the result of this analysis (some of the weaknesses and strengths are related with particular countries).

Table 1. Strength and weakness in MRP post-graduate education

STRENGTH	WEAKNESS
Basic physics Computer science Dosimetry Environmental Physics Equipment evaluation Design of devices for Radiotherapy Mathematics and Biostatistics Quality Assurance Ultrasonics	Basic radiation physics Basic biology and medicine Internal dosimetry Environmental issues Equipment testing and acceptance Management Ethics Non-ionising radiation Physiological measurements General safety X-ray engineering *Adequate European view*

Common strengths for all participants were basic physics and dosimetry.
Common weaknesses were non-ionising radiation, physiological measurements, X-ray engineering, general safety issues and the European view on the education.

From this analysis areas for collaboration between various countries were easily established. Several countries decided to apply in EC for funding joint education courses with Eastern Europe.

It was agreed that additionally to the basic professional education on Diagnostic Radiology, Nuclear Medicine, Radiotherapy, Non-ionising radiation, Imaging and Radiation Protection some knowledge on the following subjects will be of importance for the further development of the physicist:

- Management
- Cost benefit analysis and financial planing
- Contract negotiation and Policy writing
- Protection of intellectual property
- Quality issues in medical technology

It was agreed that an International Working Group should be formed to develop, in collaboration with EFOMP, IAEA, CEC and other Institutions and Organisations in the field, the Syllabi for education schemes to provide a basis for a future harmonisation of European education in MRP.

TRAINING AND CONTINUOUS PROFESSIONAL DEVELOPMENT

The discussion began with the defining of the contents of the activity. This was agreed as:

Prescribed practical work which takes place during or after specialist education aimed at developing appropriate skills which are necessary to perform correctly and safely the profession or specialisation.

Following directly from the definition, the question of entry requirements arose. It was agreed that most of the countries require level 2 to be acquired before the beginning of training. It was generally agreed that the EFOMP framework for the 5 levels of career development (please see the EFOMP ETP paper) is appropriate to be used in this case and completion of 3rd level (basic training) is the point at which a hospital physicist can start to performing routine work unsupervised. However, there were various opinions on the breadth and depth of the basic training (from 6 months to more than 2 years).

Further the place/body of training was discussed and it was generally agreed that the Training Centres should be either large hospital departments or a well organised consortium of smaller ones. It was pointed out that every country should have at least one such Centre. There was also general agreement that the work of these Training Centres as well as their schemes should be formally accredited. However Accrediting organisation/body do not exist. Similar problem was found with the question on audit of the Training Centres.

Further it was agreed that the Qualified Expert should be specialist in MRP who has completed level 4 specialist training.

The summary of this discussion was as follows:

- The EFOMP framework is appropriate for career development;
- Completion of level 3 training is an appropriate entry point for a hospital physicist to perform routine work unsupervised, however, there is some misunderstanding over the EFOMP definition of basic training in terms of breadth and depth;

- In the majority of countries no organised training schemes exist;
- Training should be carried out in accredited Training Centres, and every country should have at least one such Centre;
- Accredited Training Centres should be either large hospital departments or a well organised consortium of smaller departments;
- There must be a full formal accreditation process for Training Centres and schemes;
- There must be a formal process for the audit of Training Centres;
- There is a confusion over the definition of the term Qualified Expert, However, this Conference agreed that the QE(r), who is a specialist in MRP, will have qualification on level 4 training.

It was agreed that a collaboration on courses for Continuing professional Development should be made with the EE countries.

It was agreed International working groups to be formed on the Syllabus for the training schemes and on Accreditation and Audit (minimum requirements) for Training Centres , who are to develop in collaboration with EFOMP, IAEA, CEC and others Institutions and Organisations in the field the base for a future harmonised European Training in MRP.

ACCREDITATION

The discussion began with describing the levels of the accreditation process of an education scheme:

1. Local Assessment
2. National Assessment
3. National Accreditation
4. European Accreditation

The contributors to the process were identified as:

- Internal Peer
- External Peer (Agency, Organisation..)
- Customer (including students)

The Strengths and Weaknesses of the Assessment were analysed as shown in table 2 below:

Table 2.

STRENGTH	WEAKNESS
Experience Economy of efforts Market awareness	External acceptance Information, Language difference Standards/Legislation difference Technological difference University structure difference

The Strengths and Weaknesses of the Accreditation were analysed as shown on Table 3 below:

Table 3.

STRENGTH	WEAKNESS
Broad perspective Connection with other bodies Independence Market knowledge	Credibility Lack of uniform European Method Information, Language difference University structure difference Lack of guidelines

The major problems in this process were identified as :

- Lack of unified procedure
- Lack of international guidelines
- Critical mass of assessors/accreditors
- Mobility

A special need of inter-evaluation of post-graduate education schemes was expressed. It was agreed International working groups to be formed on the Assessment and Accreditation who are to develop in collaboration with EFOMP, IAEA, CEC and others Institutions and Organisations in the field the minimal requirements for Accreditation of the Education and Training Centres on MRP.

CONCLUSIONS

The requirements and summaries of the discussions were revised on the final Panel Discussion of the Conference where it was agreed five working groups to be formed on:

- Syllabus for Education Schemes;

- Minimum requirements for Education Centres (Accreditation and Assessment);
- Syllabus for Training Schemes;
- Minimum requirements for Training Centres (Accreditation and Audit);
- Terminology and Interpretation of EU legislation.

The groups will develop the respective questions and will prepare their conclusions in order to be accepted at the following Professional Meeting/Conference.

The delegates assessed highly this Conference and its organisation. Strong need was expressed that the Organisers should seek further EC support for a following Conference to be prepared together with EFOMP after 2-3 years. It was also agreed that the for the post-Conference book contributions for as many as possible European countries should be collected and the book distributed throughout Europe for strengthen the professional contacts. In this context was agreed that a Network should be formed and the Organiser will initiate the necessary activities in this direction.

Special gratitude was expressed to the Commission of the European Communities for funding the Project and to the organisers from the Department of Medical Engineering and Physics at King's College London for their efforts for the success of the Conference.

The Conference on Post-graduate Education in Medical Radiation Physics concluded with a Declaration of Intent agreed and signed by all delegates.

DECLARATION OF INTENT

We have examined the education and training needs for medical radiation physics. This examination has identified areas, which require to be addressed in order to maximise the benefits of applying physical science to healthcare provision throughout Europe.

We declare our intent to work together to develop a programme of initiatives in education and training which will complement and integrate existing programmes. Our aim is to harmonise activities and opportunities available to students working in this area throughout Europe.

To this end we have agreed to form a Network to facilitate the initiation and promulgation of individual initiatives between members and other agencies including the European Federation of Organisations of Medical Physics, the International Atomic Energy Agency, the International Organisation for Medical Physics, the International Federation for Medical and Biological Engineering. We have further established a number of working groups to facilitate our aim.

Budapest
14th November 1994

Signed by:

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Prof. Marta Wasillevska-Radwanska	*University of Mining and Metalurgy, Krakow, Poland*
Prof. Franco Milano	*University of Florence, Italy*
Dr Monserat Ribas Morales	*Hosputal Santa Creu I Sant Pau, Barcelona, Spain*
Prof. Joaquin Gomez da Silva	*Inst. Portugues Oncologia (UNL) Lisboa, Portugal and*
Prof. Valery Orel	*Ukrainian Research Inst. Of Oncology and Radiology, Kiev, Ukraine and Ukr. Med.Phys. Soc.*
Dr Vera Laginova	*National Cancer Inst. And Slovak Medical Physics Society, Bratislava, Slovak Republic*

Dr Sonia Kovaceva	*National Cancer Inst and Bioengineering Society, Bratislava, Slovak Republic*
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Photography of the Declaration

INFORMATION FOR AUTHORS

PUBLICATION OF DOCTORAL THESIS AND DISSERTATION ABSTRACTS

A special feature of Medical Physics International (on line at www.mpijournal.org) is the publication of thesis and dissertation abstracts for recent graduates, specifically those receiving doctoral degrees in medical physics or closely related fields in 2010 or later. This is an opportunity for recent graduates to inform the global medical physics community about their research and special interests.

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INSTRUCTIONS FOR AUTHORS

The goal of the new IOMP Journal Medical Physics International (http://mpijournal.org) is to publish manuscripts that will enhance medical physics education and professional development on a global basis. There is a special emphasis on general review articles, reports on specific educational methods, programs, and resources. In general, this will be limited to resources that are available at no cost to medical physicists and related professionals in all countries of the world. Information on commercial educational products and services can be published as paid advertisements. Research reports are not published unless the subject is educational methodology or activities relating to professional development. High-quality review articles that are comprehensive and describe significant developments in medical physics and related technology are encouraged. These will become part of a series providing a record of the history and heritage of the medical physics profession.

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MEDICAL PHYSICS INTERNATIONAL Journal

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INSTRUCTION FOR AUTHORS

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[1] Institution/Department, Affiliation, City, Country
[2] Institution/Department, Affiliation, City, Country

Abstract— **Paper abstract should not exceed 300 words. Detailed instructions for preparing the papers are available to guide the authors during the submission process. The official language is English.**

Keywords— **List maximum 5 keywords, separated by commas.**

I. INTRODUCTION

These are the instructions for preparing papers for the Medical Physics International Journal. English is the official language of the Journal. Read the instructions in this template paper carefully before proceeding with your paper.

II. DETAILED INSTRUCTIONS

Paper Size: A4

Length: The maximum document size is usually 8 pages. For longer papers please contact the Editor(s).

Margins: The page margins to be set to: "mirror margins", top margin 4 cm, bottom margin 2,5 cm, inside margin 1.9 cm and outside margin 1.4 cm.

Page Layout: 2 columns layout.

Alignment: Justified.

Fonts: Times New Roman with single line spacing throughout the paper.

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Indentation: 8 point after the title, 10 point after the authors' names and affiliations, 20 point between author's info and the beginning of the paper.

Abstract: Font - 9 point bold. Maximum length - 300 words.

Style: Use separate sections for introduction, materials and methods, results, discussion, conclusions, acknowledgments and references.

Headings: Enumerate Chapter Headings by Roman numbers (I., II., etc.). For Chapter Headings use ALL CAPS. First letter of Chapter Heading is font size 12, regular and other letters are font 8 regular style. Indents - 20 point before and 10 point after each Chapter Heading. *Subchapter Headings* are font 10, italic. Enumerate Subchapter Headings by capital letters (*A.*, *B.*, etc.). Indents - 15 point before and 7,5 point after each Subchapter Heading.

Body Text: Use Roman typeface (10 point regular) throughout. Only if you want to emphasize special parts of the text use *Italics*. Start a new paragraph by indenting it from the left margin by 4 mm (and not by inserting a blank line). Font sizes and styles to be used in the paper are summarized in Table 1.

Tables: Insert tables as close as possible to where they are mentioned in the text. If necessary, span them over both columns. Enumerate them consecutively using Arabic numbers and provide a caption for each table (e.g. Table 1, Table 2, ...). Use font 10 regular for Table caption, 1st letter, and font 8 regular for the rest of table caption and table legend. Place table captions and table legend above the table. Indents - 15 point before and 5 point after the captions.

Table 1 Font sizes and styles

Item	Font Size, pt	Font Style	Indent, points
Title	14	Bold	After: 8
Author	12	Regular	After: 10
Authors' info	9	Regular	After: 20
Abstract	9	Bold	
Keywords	9	Bold	
Chapters			
Heading - 1st letter	12	Regular	Before: 20
Heading - other letters	8	Regular	After: 10
Subchapter heading	10	Italic	Before: 15, After:7,5
Body text	10	Regular	First line left: 4mm
Acknowledgment	8	Regular	First line left: 4mm
References	8	Regular	First line left: 4mm
Author's address	8	Regular	
Tables			
Caption, 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	
Column titles	8	Regular	
Data	8	Regular	
Figures			
Caption - 1st letter	10	Regular	Before: 15
Caption – other letters	8	Regular	After: 5
Legend	8	Regular	

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Manuscripts to be considered for publication should be submitted as a WORD document to: Slavik Tabakov, Co-editor: slavik.tabakov@emerald2.co.uk

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MEDICAL PHYSICS INTERNATIONAL Journal

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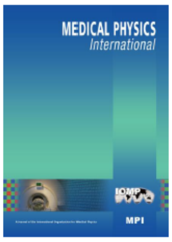

Fig. 1 Medical Physics International Journal

Equations: Write the equation in equation editor. Enumerate equations consecutively using Arabic numbers

$$A + B = C \quad (1)$$

$$X = A \times e^{i\pi} + 2lkt \quad (2)$$

Items/Bullets: In case you need to itemize parts of your text, use either bullets or numbers, as shown below:

- First item
- Second item

1. Numbered first item
2. Numbered second item

References: Use Arabic numbers in square brackets to number references in such order as they appear in the text. List them in numerical order as presented under the heading 'REFERENCES'. Examples of citations for Journal articles [1], books [2], the Digital Object Identifier (DOI) of the cited literature [3], Proceedings papers [4] and electronic publications [5].

III. CONCLUSIONS

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Format the Acknowledgment headlines without numbering.

REFERENCES

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5. MPI at http://www.mpijournal.org

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