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The relationship between physics and medicine

General Survey of Achievements and Likely Future Developments

Historical Introduction

Today the physicist brings to medicine two principles - quantitative measurement and scientific method. It is therefore very appropriate that this symposium on the Relationship between Physics and Medicine should be held in 1964, as this year is the 400th anniversary of the birth of Galileo. Not only was Galileo the father of the quantitative scientific method, but he had qualified in medicine, at Pisa, before becoming Professor of Mathematics at Padua in 1592. He therefore had close connections with both medicine and basic science. It is also appropriate that the University of Padua should be one of the promoters of this symposium, as the important association of this University with the introduction of quantitative measurement in medicine is well recognised by medical historians.

At Padua Galileo gave his lectures on mathematics at a time when no medical lectures were being delivered, and the medical students were expected to attend his lectures, and in fact made up the greater part of his audience. One has to admit times have changed!

Whilst still at Pisa, Galileo had discovered that the period of a pendulum was almost independent of the amplitude of its swing. According to legend he did this by timing a swinging lamp in the cathedral against his pulse. Subsequently, in clinical work, he reversed this procedure and timed pulses using a pendulum of variable length. He also invented a thermometer in which the expansion of gas in a bulb forced mercury along a narrow tube into a reservoir. Unfortunately the reading was affected by changes in the barometric pressure as well as by the temperature of the gas.

These two instruments for measurement of pulse rate and temperature, were developed and put into frequent clinical use by Sanctorius. He graduated in Medicine at Padua in 1582 and returned as Professor of Medicine in 1611. He may claim to be the first to introduce quantitative measurement into routine clinical practice. He is perhaps even more renowned for his quantitative metabolic studies. He used a special balance, on which he spent a considerable proportion of his life for over 30 years, measuring, among other things, insensible fluid loss both in sickness and in health.

William Harvey from England was a student at Padua in Galileo's time, graduating in medicine in 1602. He learned the laws of motion from Galileo, and came under the influence of the famous scientific school of anatomy founded at Padua some sixty years earlier by the Belgian, Vesalius. Building on his training at Padua, Harvey, on his return to England, made his great contribution to our knowledge of the motion of the blood, and perhaps even more important, established there a tradition of scientific method in medicine.

Thus the University of Padua initiated the use of quantitative measurement and a scientific approach in medicine, and influenced others to follow its example.

Elsewhere in Italy, Giovanni Borelli (1608-79) an eminent mathematician, calculated the forces produced by various muscles, and gave a mechanistic interpretation of the movements of humans and animals. Giorgio Baglivi (1668-1706) when Professor of Anatomy at Rome likened the teeth to scissors, the thorax to bellows, the heart to water works and the stomach to a grinding mill. But when he became Professor of Medicine and was concerned with the treatment of patients, he found this mechanistic explanation was inadequate, discarded theory and put the patient at the centre of the picture. Perhaps there is a moral here for physicists.

Whereas in Italy men of science were contributing to medicine, in my own country, Great Britain, physicians were contributing to science. The first book of physical science ever published in England, De Magnete, was written in 1600 by the physician William Gilbert (1540-1603), and another physician, Robert Hooke (1635-1703), was contributing to Microscopy and to Elasticity.

In the 18th century in Italy the physiologists Galvani and Volta were making the observations on electricity that were to add their names to the permanent vocabulary of that subject. Back in my work-place, Edinburgh, the physician Joseph Black was making important contributions to our knowledge of heat and chemistry.

This repeated crossing of the boundaries between different disciplines reached its climax in the 19th century with those two remarkable men, Thomas Young and Hermann von Helmholtz. Young was a practising physician who wrote an encyclopaedia of medicine. He spoke about fourteen languages and was the first to interpret the Egyptian hieroglyphics on the Rosetta Stone. More important from our point of view today, he made outstanding contributions to physiological optics, the theory of colour vision and the wave theory of light. Helmholtz was trained in medicine, but showed his great versatility by successively holding professorships in Physiology, Anatomy and Physics. He invented and applied the opthalmoscope and, like Young, wrote on the theory of colour vision, their joint theory being largely accepted even today. Helmholtz combined his love of music with practical and theoretical studies of the mechanism of hearing and of voice production.

In almost all the instances I have cited, the man concerned had a sufficient knowledge of both medicine and physics to make contributions to both subjects. This could not last. Arturo Castiglioni, the medical historian and one-time teacher in Padua University, writing of the 17th century, I repeat the 17th century, said, « Science became experimental: medicine followed philosophy because philosophy itself turned to Nature, to keep step with the natural sciences, chemistry, and physics, fields in which physicians intuitively realised that the secrets of life were to be most directly sought. Objective criticism and collaboration became indispensable from the very character of these studies. The earlier philosophers could by themselves in the silence of their studies create the basis of philosophic systems without being concerned with what was being produced about them, but the investigator of this century, desiring to explore physics and botany and chemistry, could not remain by himself. He had to seek the aid of his companions in research; he had to give such aid himself ».

If Castiglioni felt this to be true of the 17th century how much more is it true today when all these fields of knowledge have expanded so remarkably. No one of us can know the whole of medicine or the whole of physics, let alone both. We must achieve effective collaboration between physicists and clinicians. Let us look briefly at some of the fields in which such collaboration is being attempted.

I) *Radiations*

The largest single field of work for physicists in medicine is the measurement of radiations. X-rays, γ-rays and other radiations from radioactive substances are measured for purposes of radiotherapy and radiation protection. These matters will be dealt with in some detail by other speakers at this symposium, so I will not enlarge on them now. Physicists are working on instrumentation problems in X-ray diagnosis being concerned with image amplification systems and quantitative measurements for the determination of, for example, the calcium content of bones. The measurement of radioactive materials for medical diagnostic and research purposes is a vast field for the application of physics to medicine. Radioactive materials provide an extremely sensitive and powerful tool. They are being used for the measurement of blood flow in various organs; for the detection and localisation of tumours; for the investigation of thyroid, lung, liver and kidney function; for the measurement in haematology of red cell and plasma volume and red cell and platelet survival; for the determination of absorption and metabolism of vitamins, iron, calcium and fats; and for the investigation of electrolyte and water balance. Thus there is hardly a branch of medicine in which they are not being applied.

Still keeping within the spectrum of electromagnetic radiations, ultra-violet, infra-red and microwaves are all used clinically and may require quantitative measurement by the physicist. Sound waves form another type of radiation which is extensively measured in the investigation and treatment of deafness. Ultrasonic radiations are at present in diagnostic use, and hold much promise for the future as a supplement to X-ray investigations. Developments in instrumentation are in progress giving various methods of presenting the information obtained by ultrasonic pulse echo-sounding, and a period of close collaboration between those developing systems of data display and the clinicians wishing to utilise the information will be necessary in order to correlate the displays with other clinical findings.

Therapeutic use of ultrasonic radiation, with which the name of Professor Arslan of Padua is closely linked, is another field in which the quantitative measurement of radiation by the physicist has been of help to the surgeon.

II) *Pressure Measurement*

I will turn now to the measurement of pressure, which is essentially a problem in physics, but which has many clinical applications. Solely within my own Department, the following wide variety of pressure measurements have been made. Normal systolic and diastolic blood pressures using an arm cuff but with various external transducers; automatic periodic recording of systolic and diastolic blood pressure; pressure within the heart measured by cardiac catheterisation for the diagnosis of heart disease; pressure in the vena cava to observe the effect of the weight of the uterus in pregnancy; pressure in the portal vein to observe the efficacy of a surgical portal-caval shunt; pressure in spinal blood vessels for the surgical control of paralysis caused by excessive pressure in these blood vessels; pressure in the brain as a guide to surgical decompression; pressure in the eye for the investigation of glaucoma; pressure between teeth to indicate forces displacing teeth in children wearing a brace for the correction of scoliosis; pressure in the bronchus for the investigation of the mechanism of bronchospasm; pressure in the oesophagus as a cause of bronchial constriction; pressure in the bile duct as a guide to the flow of bile and the effect of drugs; pressure in the kidney in the investigation of kidney disease; pressure in the uterus in obstetric research; and pressure measurements in the stomach and large and small intestines to investigate the motility of the gastro-intestinal tract and recovery of function after operation.

There is scope for great ingenuity by the physicist in devising new methods of pressure measurement suited to such a variety of clinical problems. It is absolutely essential that there should be close collaboration between the clinician and the physicist to ensure that the most relevant measurements are made. Sometimes pressure itself is the parameter of interest, but sometimes it is measured so that the flow of fluid or the dimension of an organ may be inferred. A full discussion of the measurements is essential.

III) *Electrical activity of the Body*

Physicists are also involved in the measurement of the electrical activity of the body, as, for example, in electrocardiography, electroencephalography, electromyography and neurophysiology. Special applications of these techniques are used in foetal electrocardiography, measurement of the activity of the uterus and in the electrical measurement of eye movements. Not only are there difficult scientific problems to be overcome in making some of these measurements, but advanced electrical and mathematical methods may be employed in the quantitative analysis of the recorded electrical waveforms.

Instead of measuring the electrical activity of the body, externally generated electricity may be applied to the body. Thus the physicist will collaborate with the medical neurologist in the examination and testing of nerves, with the surgeon in the design of electrical defibrillators to restore rythmic heart function, with the cardiologist and heart surgeon in the design and use of electrical pacemakers for the heart as in Stokes-Adams disease, and with the specialist in physiotherapy in a variety of electrical methods of treatment.

IV) *Gas Analysis*

Physicists are collaborating with anaesthetists, chest physicians and respiratory physiologists who have a common interest in wishing to know the chemical constitution of gases administered to or exhaled by patients. The methods of gas analysis used in the past have been volumetric and chemical but are tedious and time consuming. The application of physical methods may demand of a physicist a knowledge of such diverse branches of physics as thermal conductivity, mass spectrometry or infra-red absorption spectroscopy.

V) *Bio-engineering*

Physicists are also working in those branches of medicine which are concerned in one way or another with the body considered as a machine. They have been concerned with the development and use of heart-lung machines which can temporarily take over the functions of these two organs during surgical operations. Power operated artificial limbs and servomechanisms are being designed for the use of disabled people, artificial kidneys are prolonging the lives of many people, the mechanical properties of metallic and plastic splints and prostheses used in orthopaedic surgery are under investigation, and the strength and elasticity of skin are being measured for plastic surgeons.

VI) *Optical Instrumentation*

The physical principles of optics have been applied to medical instrumentation in spectacles, laryngoscopes, bronchoscopes, gastroscopes and cystoscopes. Recently developments have taken place in fibre optics, that is the « piping » of light along thin fibres of glass or transparent plastics by multiple internal reflections. These developments are being applied rapidly to medical endoscopy and will mean that future endoscopes will not need to be rigid straight tubes. Medical photography, microscopy and time-lapse microscopy embody physical principles applied to medicine, and modern clinical biochemistry is depending more and more on optical methods, such as colorimetry and turbidimetry, for analysing body fluids.

This catalogue of the applications of physics to medicine could easily be extended, but I hope I have said enough to show that there is hardly a branch of medicine or surgery where physics is not usefully applied, and indeed there are some branches in which the daily application of physics is essential to the best clinical work. With this vast field of interaction between physics and medicine, how are we to ensure effective collaboration between the clinician and the physicist? I will first look at the relationship between the clinician and the physicist. I will give some consideration to the training of the physicist, and then I will discuss the organisation of physics applied to medicine.

Clinician-Physicist Relationship

The nature of the training of clinicians and physicists inevitably gives them a different outlook. The clinician is trained to consider a particular patient. The physicist is trained to look for generalities - often abstract generalities. But both are professional men trained in special branches of knowledge and each has his own contribution to make to the problems at hand.

The medical man should not assume that the scientist is all-knowing in his field of science. Physics is a vast subject. The physicist should not be regarded as a miracle worker. At the other extreme, neither is he a person to be asked to make a measurement, or devise a piece of apparatus, without being told the reason for the measurement or the need for the apparatus. He should not be presented with a partially interpreted problem but should be given the opportunity of discussing fully the physical principles involved and of asking questions relating to the clinical aspects. Only by a full interchange of views will the best collaboration be achieved.

The physicist also has to learn to adapt his thinking to a clinical environment. Only very seldom is a measurement required to 0,1% or even to 1% accuracy. Measuring instruments should instead be simple to operate and rugged and reliable in use, so that many measurements can be made in a short time. The physicist must realise that the physician and surgeon often cannot enjoy the academic scientist's luxury of reserving his judgment until more facts are known. The clinician must frequently make a decision on such facts as may be available - delay may put a patient's life in jeopardy. The surgeon who has to take quick decisions during operations, should however appreciate the scientist's wish to reserve judgment in cases where such instant decisions are not essential. This withholding of judgment is not a sign of weakness but a wish to find the full truth. The speed of decision should be matched to the requirements of the situation. When driving a car the physicist probably makes his decisions as quickly as the surgeon.

By working closely together a proper understanding of one another's viewpoints will be obtained. We should not strive to make clinicians and physicists think alike, but must try to ensure that their thinking is complementary, bringing the benefits of physical science to the medical treatment of the individual patient.

Training of the Physicist

It is obvious that the more medicine the physicist knows and the more physics the clinician knows the easier will be their joint work. But I have already indicated the difficulty presented by the vast amount of knowledge in each of these fields with the consequent difficulty of knowing one of them, let alone both. Perhaps it is easier for the physicist to cross the boundary from an exact science and its generalities, to medicine with its interest in the particular patient, than it is for the clinician to cross the boundary in the other direction. In any case it is usually a clinical rather than a physical problem which is the ultimate problem they are both trying to solve. Consequently I believe the physicist has a special reresponsibility to learn about clinical matters rather than the clinician to learn about physics. I do not wish to imply that the clinician should not learn *any* of the physics relevant to his special interests.

The physicist must keep abreast of advances in physics, and must remain an expert in those branches of physics he is applying to medicine. So much is obvious. But when consideration is given to the biological knowledge a medical physicist should acquire, matters are not so obvious. I believe a physicist should learn what has been called « geometrical anatomy », namely the spatial relationships of body organs, and he must have a basic knowledge of physiology. Thereafter I think his studying must depend upon the branch of medicine to which he is applying his knowledge of physics. The physicist working in radiotherapy will read something of the nature of cancer and its modes of spread, he will learn the basic biology of cell division and differentiation and the fundamentals of radiobiology. Many have been drawn deeply into this latter field of study. The physicist using radioactive materials in the study of, say, kidney function will learn the detailed physiology of the kidney; the physicist measuring blood pressures will study haemodynamics and the detailed physiology of the blood circulation; the physicist working in audiometry will study the theory of hearing and the detailed anatomy and physiology of the ear.

It is one of the delights of working in medical physics that one is constantly meeting new challenges and acquiring new knowledge in other biological fields without having to become an expert in those fields. One's clinical colleague is the expert and onc learns sufficient to achieve effective collaboration with him.

However, effective collaboration depends not only on knowledge but on organisation, and it is the organisation of physics applied to medicine which I now wish to discuss.

Organisation of Physics applied to Medicine

The application of physics to medicine has nearly always started by the appointment of a single physicist to a single department in a single hospital. Similar developments may have occurred in other departments or other hospitals in the same region, with the result that several very small medical physics organisations have evolved. Such small organisations are open to the following objections:

I) Economic use is not made of the often expensive equipment the physicist requires. Alternatively the department is poorly equipped with apparatus with resulting inefficient use of the physicist's time, and a poor physics service to the clinician.

II) The physicist does not have other people trained in the same discipline with whom to discuss his problems, and in particular may lack guidance from a very experienced physicist.

III) The clinician can only draw on the scientific knowledge of the limited number of physicists working with him.

IV) The physicist may well be called upon to carry out tasks requiring far less than his full abilities, tasks which would be more economically carried out by a suitably trained technician. This is also bad for the morale of the physicist. The smaller the staff the less the possibilities of proper division of labour.

In consequence there has been a tendency in recent years to amalgamate small medical physics departments or to ensure that growth is concentrated in a few large centres. This has certainly happened in Great Britain and I believe this is also the position in Sweden and the Netherlands. The representatives here from other countries might be able to confirm this trend in their own countries.

Whilst a central service covering a large area is efficient in the use of scientists and equipment and provides a pool of scientists with varied experience on whom clinicians may call, care has to be taken to ensure that the scientists do not become remote from the clinicians. Close contact must be maintained and the scientist must feel identified with the clinical problem or problems on which he is working. This close contact can sometimes be arranged by seconding a member of the central medical physics organisation to work with a particular clinician for an agreed period. The scientist must retain contact with the central organisation so that he may keep abreast of advances in branches of physics other than that with which he is immediately concerned. Another very important advantage is that the central organisation can also provide help to a clinician who requires less than the full-time services of one physicist or technician.

I believe that a central medical physics organisation coupled with an intelligent use of secondment is most efficient in utilisation of equipment and physicists and effective in giving the clinician the close help and advice he requires. One further advantage of the large organisation which is so often overlooked is that it can provide reasonable career prospects for the physicist. Frequently the small physics section is unable to provide adequate advancement for the experienced scientist.

I must emphasise, however, the need for a central organisation to ensure that collaboration is close. The physicist must not only work in his laboratory but must go into the clinic, into the ward and into the operating theatre. Only in this way will he come to appreciate the clinician's needs and problems. Only in this way will a true partnership be established.

Future Developments

What developments may we expect in the future? In general terms we may expect that medicine will become more scientific. We will substitute more objective quantitative facts for subjective qualitative opinions, but I do not think we should anticipate medicine becoming an exact science. The human mind and body and the diseases to which they are subject are extremely complicated, so the « art » of medicine will be with us for a long time to come.

This increase in the application of science to medicine will require the employment of more physicists in this field. At present in Great Britain, approximately 250 physicists are employed directly in the National Health Service and about an equal number is employed on similar work in universities and biological research establishments. As we have an overall population of just over 50 millions, we have one medical physicist for roughly every 100,000 of population. In Great Britain medical physicists are increasing by 7 or 8% per annum, but in countries at present having less than one medical physicist per 100,000 of population the rate of increase must be expected to be appreciably greater than this.

Among other things, these physicists will be devising more and more equipment for the measurement of more and more physiological variables. In the operating theatre and in some intensive care wards this measurement may be almost continuous. The number of measurements will be so great that automatic methods of processing data will be required. Such methods of automatic data processing will also be applied to the handling of patients' records, with the result that this information will be far more readily available than it has been in the past both for treatment of the patient and for statistical purposes and research. Chemical analysis in clinical biochemistry will be automated as will the reporting of these analyses to the patients' doctors. We may anticipate a greater use of artificial electrical control of muscles, perhaps extending to the bladder, or even the intestines, the equivalent of the existing electrical « pacemaker » for the heart. We will see a general increase in what might be called « spare parts » for the body, and may develop further sensory aids for the blind which have already started with the construction of a simple echo-sounder to help the blind man avoid obstacles. One of the great challenges for the future is to arrive at a better understanding of the working of the human brain. If ever there was a field requiring interdisciplinary collaboration this is it. Advances may be made by various combinations of psychiatry, psychology, physiology, pharmacology, anatomy, physics, chemistry, mathematics, and electrical engineering. Completely new discoveries will be made in physics and no doubt some will be applied to medicine as rapidly as were X-rays nearly 70 years ago, or as were lasers, intense sources of pulsed coherent light, in the early 1960's.

However exciting these new discoveries and developments may be, they are not the things which bring most hope for the future. I am sure the physicist hopes that the application of physics to medicine will not only be directly *useful* in day to day clinical work, but that the application of scientific method will lead to a better *understanding* of both disease and its treatment. Thus, for example, in the field of radiotherapy in which many people here are interested, physics is useful in the day to day treatment of patients, but physics and other scientific disciplines applied to radiobiology will lead to a better understanding of radiotherapy itself. Such understanding will come slowly and we should not expect too much too soon. But in the long term true understanding will be the greatest contribution of science to medicine.

INTERVENTI SULLA RELAZIONE

A. ROSTAGNI

La relazione del Dr. Greening reca una risposta al quesito, se sia preferibile tenere dei fisici isolati nei diversi reparti medici, o aggregarli in un reparto fisico. Essa è decisamente favorevole a quest'ultima soluzione, come la più redditizia, e quella verso la quale si sono orientate gradualmente le varie istituzioni ospedaliere ed universitarie britanniche. Occorre tenerla presente, considerando che il reparto fisico dovrà costituire un luogo d'incontro anche per quei fisici che, per esigenze di lavoro, dovranno essere stabilmente aggregati a determinati reparti medici (per es. ai reparti di radioterapia).

M. PIETROJUSTI

Dobbiamo essere grati al Dr. Greening per aver trasferita la nostra attenzione dal settore radiologico a quello ben più vasto della Medicina, fornendoci altresì la dimostrazione dei molteplici apparati che possono essere forniti dalla Fisica.

Alcune sue impostazioni possono essere pienamente sottoscritte qualora si tenga mente agli indirizzi indicati dal Prof. Favilli nella sua relazione e sui quali si sono avuti gli unanimi consensi dei partecipanti a questo Convegno.

Dalla relazione del Dr. Greening si trae, ancor più, la conclusione che in un prossimo futuro il più diretto collaboratore del Medico, sarà il Fisico.

Se accettiamo questa conclusione, vengono meno molte osservazioni, legate a questioni di dipendenza o di inserimento, poiché i rapporti tra Medico e Fisico vanno trasferiti sul piano della più stretta collaborazione. Sappiamo come le collaborazioni siano valide allorquando sono imposte dalla necessità e avvengano nel pieno rispetto delle reciproche competenze.

Decade inoltre l'altra perplessità, dovuta forse alla non completa conoscenza delle varie forme di collaborazione che saranno possibili tra Fisico e Medico particolarmente quella se sia opportuno o meno che il primo venga a contatto con l'ammalato.

Se inoltre ammettiamo di trovarci in una fase di evoluzione nella Medicina — e questo Convegno ne è la diretta conferma — dobbiamo essere portati a rivedere anche molte impostazioni del passato frutto di situazioni superate o che sono per esserlo.

I Dottori Greening, Warrington e Meredith hanno insistito sulla necessità che la collaborazione tra Medico e Fisico sia la più intima possibile e sulla opportunità che essa venga esattamente predisposta, per trasformarsi in una vera comunione. Possiamo dire che questa è la base di ogni futura evoluzione verso il metodo sperimentale che, nato proprio nell'Università di Padova, è oggi più che mai attuale nel campo della Medicina.

RISPOSTA DEL RELATORE

J. R. GREENING

I should like to return to the question of collaboration between physicists and clinicians. Although a good organisation can help collaboration it will be of no avail if the two essential requirements are lacking, namely a clinician who really wants to be helped, and a physicist who wants to provide that help. If the physicist does not have a genuine desire to help solve clinical problems or aid in clinical treatments he should not enter the field of medical physics. As Dr. Casnati said, the great majority of physicists or graduating enter some branch of applied physics. They apply their knowledge of physics to problems in oil refineries, chemical plants, the processing of fibres, the production of electricity, or the control of nuclear energy; etc. Medical physics is another branch of applied physics. There is no need for a physicist to be ashamed of applying his knowledge to the solution of a problem which is not ultimately physical. If he must undertake research in pure physics he should stay out of medical physics. Personally I believe there is a greater need to apply physics to biological and social problems then there is to explore some branches of pure physics. I can assure physicists that there are worthwhile and satisfying problems for them in the application of physics to clinical diagnosis, treatment and research. The work is satisfying both scientifically and socially.

At the begining of my talk I said physics brought to medecine quantitative measurement and scientific method. From the earlier discussion I have formed the impression — probably incorrectly because of my ignorance of conditions here — that you wish to reserve the scientific method of universities and have only the quantitative measurement in hospitals. Surely you need both in both places. My own Department is financed jointly by the University of Edinburgh and by the Hospital Board for the South Eastern Region of Scotland. We do not find we are able to drow a sharp line between research, development and routine clinical application. To-day's research is to-morrow's development and the day after to-morrow's routine clinical application. Recently I calculated that we were collaborating with over 20 University and Hospital departments in more than 50 projects, and sometimes it was difficult to determinate whether the University or a hospital was the body involved.

This collaboration is possible given good will on both sides. Some of our clinical colleagues are easier to collaborate with than others. No doubt, for their part, thay find some members of my staff easier to get on with than others. Let me show you a very little mathematics. If « n » people can all meet one another in the course of their work then there will be n(n — I)/2 pairs of people between whom personal antipathies may arise. I am glad to say that in my own organisation we have less than 0,5% of the theoretical maximum! But whatever your organisation you are dealing ultimately with individuals just as the clinician is dealing with individual patient.

CONCLUSIONE DEI MODERATORI

M. LENZI e C. POLVANI

Con la seduta di questo pomeriggio si è conclusa la trattazione del primo dei tre temi oggetto dei Colloqui, quello centrato sui problemi generali di organizzazione, nei rapporti che debbono esistere tra Fisica e Medicina. Con domani si inizia la parte dedicata alle applicazioni pratiche della Fisica nella Radiologia medica.

Pertanto, anche per incarico del Prof. Lenzi, cercherò di trarre alcune sommarie, parziali e provvisorie conclusioni dalle relazioni e dalle discussioni di questi due giorni di lavoro, non senza aver prima ancora una volta ringraziato tutti coloro che hanno contribuito a presentare e ad analizzare il tema posto all'ordine del giorno.

Per ragioni di brevità limiteremo il discorso ai rapporti tra Fisica e Medicina pratica, con particolare — ma non esclusiva — attenzione alla Radiologia. Una parte delle nostre conclusioni potranno essere applicate anche ad altre forme di collaborazione fisico-medica, ma un campo ci sembra che resti al di fuori di queste brevi considerazioni: ci riferiamo al campo della Biofisica, intesa nel senso che è stato illustrato dalla relazione del Prof. Favilli.

Preparando queste parole di chiusura ci siamo accorti, il Prof. Lenzi ed io, che le conclusioni possono essere raccolte, per comodità di esposizione, in tre gruppi. Il primo gruppo contiene alcuni principi ed orientamenti generali, che sono stati approvati dagli intervenuti e che possono costituire punti di riferimento abbastanza precisi, acquisiti per mezzo della discussione.

Il secondo gruppo di conclusioni riguarda piuttosto alcune distinzioni e differenziazioni che sono state poste in evidenza in questi giorni e che si presentano piuttosto meritevoli di considerazione.

Il terzo gruppo di conclusioni riguarda infine un insieme di iniziative pratiche, diremmo di passi concreti da esegure per rendere operanti i principi e gli orientamenti frutto della discussione.

Esponiamo dunque ordinatamente queste considerazioni perché servano all'ulteriore svolgimento del Colloquio.

Cominciamo con i *principi e gli orientamenti generali* che sono risultati condivi da tutti — o quasi tutti — i presenti.

Una prima affermazione è la seguente. Il Fisico medico (o Fisico d'ospedale: la nomenclatura non ci è sembrata sufficientemente unificata tra i vari oratori, cosicché sul momento useremo le due espressioni indifferentemente) è chiamato di regola a volgere una attività mista, composta da azioni di servizio (la cosiddetta « routine ») e da ricerche tecnico-scientifiche. I modesti compiti ripetuti che fanno parte del lavoro quotidiano possono contribuire in maniera importante alla formazione ed al perfezionamento del giovane fisico medico, portandolo tra l'altro a conoscere la varietà dei problemi clinici e le difficoltà della professione medica. Essi favoriscono anche le occasioni di contatto e di discussione con i sanitari e con i loro collaboratori. Si tenga presente anche che l'attività di routine induce alla conoscenza dei problemi di cura dell'ammalato, cosicché il Fisico viene portato a partecipare della forma mentis propria delle professioni sanitarie (Piemonte).

Su questa opportunità, anzi necessità che il Fisico medico esegua anche lavori di routine hanno parlato tra gli altri il prof. Rostagni, il prof. Benassi e il dott. Meredith.

D'altra parte deve essere consentito al Fisico d'ospedale di condurre indagini e ricerche tecnico-scientifiche applicate. Gli spunti e le idee gli saranno sovente offerti dal suo quotidiano lavoro. Fino dalle conferenze introduttive dei professori Favilli e Ageno, molti oratori hanno sottolineato che l'attività di ricerca fa parte delle esigenze di ordine intellettuale di un laureato in Fisica e che ad essa egli deve poter dedicare una parte del suo tempo.

Un secondo orientamento generale emerso dalle relazioni e dagli interventi riguarda quelle che potremmo chiamare le buone condizioni di lavoro che debbono essere realizzate per soddisfare le attese del laureato in Fisica che intende dedicarsi alla Fisica medica.

Tra queste attese una è stata ricordata dal dott. Casnati: il Fisico non vuole semplicemente essere a disposizione di un ospedale o di un istituto come un esperto che viene consultato su singole questioni, ma desidera entrare a far parte della équipe ospedaliera o di istituto, portando in essa il contributo del proprio lavoro e dei propri studi. Per far questo ha bisogno di una adeguata dotazione di strumenti e di apparecchi, di un tecnico (o di più tecnici) che lo aiutino e di un poco di spazio. Solamente così egli può effettuare esperimenti e misure ed avviare programmi di ricerca; solo a queste condizioni egli sente di collaborare veramente e compiutamente, offrendo l'apporto della propria preparazione culturale e capacità tecnica.

In altre parole il Fisico d'ospedale domanda che si realizzi a suo favore un adeguato ambiente di lavoro (strumenti, tecnici, spazio) in cui egli possa provvedere alle esigenze di servizio, alle indagini e alla ricerca tecnico-scientifica.

Un altro orientamento che ci è sembrato accolto dai relatori e dall'uditorio riguarda la necessità che si provveda rapidamente a definire un opportuno « status » del fisico nell'ambiente medico di cui fa parte. Può essere che in alcune situazioni iniziali o particolari il Fisico sia chiamato a collaborare al livello del cosiddetto « tecnico laureato », con la subordinazione che questa qualifica comporta. Ma tale condizione non può rappresentare che una fase di sviluppo, accettabile da giovani neo-laureati, in attesa di giungere ad una collaborazione su una base di parità con i colleghi medici di equivalente preparazione ed esperienza.

Questa prospettiva di collaborazione sarà di attrarre fisici di valore a lavorare in ambiente medico e consentirà al nostro Paese di avere una produzione scientifica fisico-medica di alto livello. Tale ci è sembrato il senso della discussione di questi due giorni, in particolare degli interventi dei professori Rostagni e Benassi.

Accanto allo status vi è il problema della carriera, cioè dello sviluppo della personalità professionale del Fisico medico. Se si richiede, come è opportuno che si faccia, il « full-time » al Fisico, si deve offrirgli la contropartita di potere impegnare se stesso a fondo ed in una lunga prospettiva di tempo. Tra gli altri, il prof. Lenzi ha richiamato l'attenzione su queste esigenze di carriera.

Molti interventi hanno poi ripetuto la necessità di adeguare la retribuzione economica dei fisici a fronte di quelle dei colleghi medici, onde il paragone non ponga a disagio nè gli uni nè gli altri.

Passiamo ora a considerare brevemente *alcune distinzioni o ripartizioni*, che sono state più volte richiamate.

Una prima distinzione è quella tra Fisici medici che lavorano negli Istituti universitari di Radiologia e Fisici medici che lavorano negli Ospedali. I moderatori di queste sedute raccomanderebbero che questa distinzione non venisse troppo sottolineata e favorita nella realtà di tutti i giorni, pur riconoscendo che essa si basa su fatti precisi e trae origine dalle caratteristiche di uniformità e di ripetizione di gran parte del lavoro ospedaliero, mentre nel lavoro universitario l'attenzione è portata prevalentemente sulla ricerca scientifica.

Non potendo in questo momento, per brevità, ricordare le ragioni che suggeriscono ai moderatori di non insistere su questa suddivisione, faremo solo la considerazione seguente. Una differenziazione troppo netta tra Fisici degli Istituti universitari e Fisici degli Ospedali potrebbe impedire in un domani la circolazione dei Fisici stessi, intesa come capacità e possibilità di trovare lavoro nei diversi ambienti sanitari. Non sembra prudente cioè costituire due gruppi di Fisici medici alquanto separati tra di loro, i quali tra qualche anno potrebbero non essere più in grado di avvicendamento — secondo necessità o contingenza — nelle diverse sedi e istituzioni mediche. Queste considerazioni sono espresse proprio nell'interesse dei Fisici medici.

Una distinzione che pure è stata fatta riguarda invece i tempi e gli stadi di sviluppo dell'attività di Fisica medica in un determinato ambiente sanitario. L'inizio di tale attività avviene nella maggior parte dei casi come avviamento di un piccolo reparto, costituito da un laureato aiutato da un tecnico. Si deve auspicare che tale reparto, nato entro la divisione radiologica di un Ospedale o entro un Istituto universitario, possa gradualmente (secondo quanto prospettato dai professori Dalla Volta e Cignolini e dallo stesso relatore prof. Fossati) crescere di importanza e — almeno nei casi di maggior rilievo — acquistare col tempo una certa autonomia.

Questa evoluzione può portare a due diverse situazioni a seconda dell'ambiente considerato. Nell'Ospedale lo stadio ultimo dell'evoluzione conduce (o meglio condurrà, col tempo; perché è da prevedere un'attesa abbastanza lunga per la formazione e la crescita) alla costituzione di un servizio o di una divisione ospedaliera di Fisica medica, che collabori con tutte le divisioni che hanno necessità di approfondire problemi fisici o di richiedere prestazioni tecniche e servizi. Nell'Università lo stadio finale è rappresentato invece dalla formazione di una cattedra o di un Istituto di Fisica medica (la cui sede naturale sembra essere la Facoltà di medicina e chirurgia), con i compiti tradizionali di insegnamento e di ricerca, cui si aggiungono nel nostro caso specifico compiti di collegamento e di collaborazione tecnico-scientifica.

Queste prospettive si presentano ardue; alcuni forse pensano che esse siano un poco avveniristiche. Ma noi dovevamo ricordarle, confortati anche dalle parole che ci hanno dette il prof. Spiers, il prof. Fossati, il dott. Meredith, il prof. Caldirola.

Un'altra forma di differenziazione è stata più volte ricordata nel dibattito, dopo che di essa si era già parlato nelle conferenze inaugurali. Essa consiste nel riconoscere che quando si parla genericamente di Fisica applicata alla Medicina si allude oggi ad un campo del sapere estremamente vasto, in cui esistono ripartizioni e specializzazioni. Cosicché è possibile prevedere che tra i Fisici medici (ai quali abbiamo finora senza distinzione riferito le nostre considerazioni) vi saranno alcuni studiosi maggiormente impegnati in problemi di Fisica delle radiazioni e di dosimetria, altri rivolti agli studi delle attività elettriche degli organi del corpo umano, altri ai problemi di « health physics » (la cosiddetta Fisica sanitaria, che invero è una specializzazione piuttosto a se stante della Fisica applicata) ed altri ancora che lavoreranno prevalentemente in Elettronica medica, secondo quanto abbiamo ascoltato nella relazione del prof. Francini.

Vogliamo ora accennare ad *alcune iniziative* che potrebbero favorire nel nostro Paese un più vasto inserimento dei Fisici nel mondo medico. Queste iniziative potrebbero costituire i primi passi concreti da compiere o da favorire nel prossimo futuro, per dare un seguito al Colloquio di Roncegno.

Da parte di diversi oratori è stato suggerito che nello sviluppo della regolamentazione sanitaria italiana si favorisca la istituzione di posti di ruolo per Fisici negli organici degli Ospedali di maggiore importanza, che abbiano consistenti reparti di terapia radiologica. Tutto quanto può aiutare la realizzazione di questa prospettiva aiuterà assai l'inserimento, con posizione adeguata ed invitante, dei Fisici nei maggiori Ospedali.

Altri interventi (ricordiamo quelli dei professori Benassi e Caldirola) hanno auspicato che vengono studiate le forme per cui sia possibile avere negli Istituti universitari di Radiologia posti di assistente ricoperti da laureati in Fisica.

Solo gli anni venturi potranno dirci se questi voti si realizzeranno felicemente e tempestivamente, assieme a quelli, più impegnativi e bisognosi di attento studio in sede competente, che riguardano la formazione di Istituti e Cattedre universitarie di Fisica per i medici. La differenziazione nei Corsi di laurea in Fisica di cui ha parlato il prof. Rostagni illustrandone in particolare l'indirizzo applicativo, sembra favorire intanto una maggiore disponibilità di giovani fisici per gli Ospedali e per gli Istituti radiologici.

Un'altra iniziativa infine potrebbe contribuire a tener vivo l'interesse sui problemi che abbiamo dibattuto in questi giorni, consentendone lo studio e il processo di maturazione. Per la verità quanto stiamo per esporre non è stato esplicitamente detto nelle relazioni e nelle discussioni, ma ci è sembrato suggerito da un insieme di fatti e di situazioni di cui siamo venuti tutti a conoscenza. I Fisici d'ospedale costituiscono oggi in Italia un gruppo abbastanza numeroso, forse tra venti e trenta unità, forse più. Il dott. Greening prevede che in Gran Bretagna si avrà negli anni prossimi un incremento annuo nel numero dei Fisici di ospedale pari al 7-8%. Egli ha anche detto che in altri Paesi c'è da attendersi un incremento annuo ancora maggiore: l'Italia sembra essere tra questi Paesi perché ci sono molti vuoti da colmare e molti posti di lavoro da istituire.

Se questa espansione si avvererà, se il numero dei Fisici medici crescerà, dobbiamo pensare che essi avranno bisogno di incontrarsi periodicamente per dibattere i loro problemi, per comunicarsi reciprocamente i risultati del proprio lavoro, a beneficio di tutti i colleghi. Insomma essi avranno bisogno di dar vita ad una qualche forma associativa per lo sviluppo scientifico della loro disciplina. Auguriamoci che questa esigenza trovi presto un'occasione e un terreno favorevole per cominciare a concretarsi.

Queste iniziative e prospettive finali possono dunque essere tenute in conto di stimolo per l'azione degli anni venturi. Con esse chiudiamo la nostra breve sintesi, che abbiamo detto provvisoria e parziale, riguardante il primo tema dei Colloqui, e ci accingiamo ad affrontare domani la seconda parte dei Colloqui stessi.

(PAGINA VUOTA NEL TESTO ORIGINALE)

Argomento precedente

Indice

Argomento successivo