Whither virology?
Trends and prospects in medical research*

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For just over three-quarters of a century the study of the viruses has furnished a most exciting chapter in the growth of the natural sciences. The story began with the observations of Ivanovsky upon tobacco mosaic disease in 1892 and of Loeffler and Froesch upon foot and mouth disease in 1898. Both studies showed that the respective diseases could be transmitted by filtered extracts from the affected plants or animals containing no recognizable bacteria. Yet the contagious material in the filtrates could neither be visualized nor cultivated. A similar mystery surrounded Reed's transmission of yellow fever to man in 1902 and that of poliomyelitis to monkeys by Landsteiner and Popper in 1908. Though history credits Buist (1886) and Paschen (1906) with the first demonstrations of virus particles in vaccinial lymph, further progress awaited technical advances in microscopy.

When I was first initiated into virus research at the National Institute for Medical Research at Hampstead in 1935, Dr J. E. Barnard was using ultraviolet photomicrography to demonstrate the elementary bodies of the pox viruses. Also W. F. Elford was studying the measurement of size based upon graded collodion filters. The then known particles including viruses were arranged in order of size from bacterium to molecule and Sir Henry Dale, in his Huxley lecture at Imperial College in 1935 entitled 'Viruses and Heterogenesis', relied upon such evidence to dispose of the argument that viruses are products of the cells of other living organisms—an argument which recurs periodically right up to the present day.

The techniques which have been pressed into use in the study of viruses are many and varied but periodically all virologists return from their chemical or physical technicalities to the question of the transmission of infection, for it has been this above all which has characterized the virus as an object worthy of study. In the early studies, transmission of infection was regarded as the corner-stone of proof that the material contained the actual causative virus of the particular disease under study. Later it became a method for artificial cultivation of the virus but alas, available experimental animals were far too frequently resistant to the transfer of infection from man. Only the monkey, the ferret, the hamster, the mouse and the fertile hen's egg remained to encourage the virologists of the pre-tissue culture era. Latterly the volunteer has been of inestimable value in permitting work upon the common cold, live vaccines and even hepatitis. Nevertheless, all work involving man as an experimental animal has immense drawbacks and can never do more than supplement that of the laboratory.

The new technical methods available for the cultivation in tissue and organ cultures have greatly extended the recovery of viruses both from diseased animals and humans and from apparently healthy persons. A vast array of viruses recovered from the animal kingdom stands revealed, many of which have been obtained from man (Andrewes and Pereira, 1972). The viruses of animals and particularly of those in contact with man through domesticity, share many characters in common with human agents. A new science of comparative virology is thus being written at the present time which includes certain of the respiratory viruses of man including influenza. Thus far it has proved impossible to say whether these animal viruses are derived from contact with man or vice versa but it is a fact that the former hard line of distinction between the viruses of animals and of men no longer exists. The bearing of this upon the origin of human viruses is no mere academic matter for it involves so practical an issue as the source of the virus of the next influenza pandemic.

Meanwhile the universality of virus parasitism encourages the belief that viruses are ancient in an evolutionary sense and that human viruses may well have evolved hand-in-hand with man in his ascent from the animal kingdom.

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Viruses as causal agents of human disease

The impact of the tissue culture method upon the cultivation of viruses from human specimens has been very great. The list of viruses recovered either from patients or from apparently healthy persons is very long and the task of associating viruses with clinical illnesses has sometimes proved difficult. The simple view of one virus, one disease, which held during the first half of the twentieth century broke down with the discovery of the numerous viruses found in the respiratory and gastro-intestinal systems. It is now obvious that the various clinical categories of respiratory illnesses are syndromes even though certain virus groups more commonly prefer to attack certain areas of the respiratory epithelium. It is also obvious that most of the entero-virus infections originating from the pharynx or intestine are subclinical and rarely invoke virus invasion of the body generally or of the CNS.

Another major consequence of the virus explosion is the discovery that many viruses exist in the form of multiple serotypes with little cross-immunity. The 33 adenoviruses, 100 or so rhinoviruses, 30 coxsackieviruses and 34 echoviruses constitute an immunological jungle which, though it helps the virus as a parasite, nullifies the efforts of those seeking to develop vaccines. In retrospect, the single antigenic species of variola, yellow fever, measles and rubella viruses are the exception rather than the rule. The three serotypes of poliovirus do not constitute a serious problem for prophylaxis, but the merry-go-round of the surface antigens of the influenza viruses is one of the important reasons for the relative failure of influenza vaccine to control the disease and the specific prevention of the common cold seems now to be insoluble even by means of a multivalent vaccine.

Nevertheless, looked at from the point of view of the causes of human illnesses, the viruses thus far recovered appear to account for most of the acute non-bacterial non-parasitic infections. Where viruses cannot be cultivated, their particles may sometimes be seen within the affected cells as, for instance, of warts or molluscum contagiosum. Some undiscovered virus species may exist as, for instance, in addition to the rhinoviruses and coronaviruses there may be other causes of the common cold. But most instances of viruses as determinants of acute disease including hepatitis and acute gastroenteritis are probably known.

The relationship of the virus to host cell in these acute infections is one involving varying degrees of damage to the host followed usually by repair. At the same time replication of the virus particles within
infected cells produces thousands of new particles identical to the original ones. As this progeny seeks release from the host to the exterior, its transmission from one infected host to the next follows the lines familiar in bacterial diseases. Vertical transmission from mother to foetus is an important additional corollary to horizontal transmission within the human herd. All such aspects of virus infection could be described as ‘orthodox’ and the immunity which is invoked, if effective, is specific. But in the past few years exploration of virus-cell relationships has revealed unusual patterns of infection.

**Latent, recurrent and chronic virus infections**

A latent infection by a virus is one in which the virus persists but causes no outward evidence of its presence. *Herpesvirus hominis* acquired probably in infancy as an acute infection of the mouth or pharynx, has the capacity to remain in its host throughout life and in an obscure locus. The recurrent herpes blisters of the lips and face constitute the proof that the virus is still active and is capable of being provoked into attack by some shock or adverse condition of the host. The whereabouts of the virus’ habitat within the body during the latent phase of infection was for long a matter of surmise. Grouping of the recurrent skin lesions in the distribution of sensory nerves strongly suggested that nerve cells might be the locus of the hidden virus. Very recently proof of the correctness of this view has been obtained by histological examination of the Gasserian ganglion and cultivation of virus from the latter at autopsy (Bastian et al., 1972).

Other examples of virus latency are now known. Both hepatitis virus B and cytomegalovirus are known to be transmitted by blood from apparently healthy blood donors. Yet we do not know where such latent viruses exist in the body though the liver and spleen may be involved in maintaining viraemia. Latent adenovirus infection of the tonsils and adenoids is perhaps of a different nature from that of herpesvirus for it appears not to be transmitted to others nor to cause recurrent infection. The virus merely survives locked within cells of the tonsils or adenoids to which it gained access at an unknown previous time. Perhaps it is because the adenovirus develops a close cell-relationship and does not have a severely destructive cellular effect that it can become latent. Indeed the ability of a latent virus to survive even when adequate serum antibodies exist to prevent its spread, suggests a failure of immune mechanisms. It is thought, however, that the virus particles in the latent state replicate at an exceedingly slow rate and transfer directly from one cell to another through contiguous cell membranes without ever becoming extracellular. When the parent host is subjected to immuno-suppression then latency may change to overt infection as with cytomegalovirus and the newly described polyoma virus.

Reference must now be made to the chronic infections induced by viruses. This of course raises the role of viruses in relation to tumours—a subject to which reference will be made later. The only chronic virus infections of man on which there is certain knowledge are those which occur in the nervous system. The herpes group of viruses again require mention in that congenitally acquired cytomegalovirus infection causes a chronic encephalitis with mental subnormality. The curious case of inclusion or subacute sclerosing panencephalitis is another example of a relatively slow infection, this time of measles virus (Dayan et al., 1967; Legg, 1967). This uncommon neurological condition which begins as a behaviour disorder and progresses inexorably to death, seems to be the consequence of a resurgence of measles virus infection acquired months or even several years before. No explanation of the exact pathogenesis is yet forthcoming.

The possibility that chronic forms of neurological disease are due to viruses was first canvassed in explanation of the New Guinea Islanders’ disease kuru. The transmission of kuru to chimpanzees has done little to clarify this issue though the chronic character of both the human and animal disease suggests a similarity with scrapie of sheep. This disease, though transmissible to mice and several other species, still remains obscure. The hypothetical virus has not been demonstrated and though it can persist in cultures of brain cells from infected animals, it has not been transferred to other cultured cells. The resistance of the scrapie agent to heat and ultraviolet light is so remarkable that doubt has been raised as to whether the agent contains nucleic acid. The prospect of a transmissible self-replicating polysaccharide is not, however, one to which I subscribe with enthusiasm. The lesson surely for us clinicians is that some forms of neurological disease hitherto regarded as degenerative in nature may be transmissible infections due to virus-like agents. The Jakob-Kreuzfeld disease and progressive leukencephalopathy already belong to this category but the hunt is on and no one can tell whether it may lead. Meanwhile it is necessary to turn away from human disease to describe some of the trends in virology occasioned by developments in molecular biological techniques.

**The virus and the cell**

(a) *The nature of viruses*

The development of methods for the mass cultivation of viruses led naturally to a study of the structure and composition of their particles. The late
Rosalind Franklin of Birkbeck College was the first to apply X-ray diffraction analysis techniques to virus particles and her concept of the tobacco mosaic virus as a helical strand of RNA on which protein sub-units are assembled externally, has stood the test of time. Coupled with advanced electron microscopical techniques the ultra-structure has now been studied in many viruses of plants, insects, animals and man and certain basic patterns have emerged. Put the TMV rod as a skein inside a host capsule of lipoprotein and embed in the envelope other virus-specified protein units with specific functions and one has the particle of a myxovirus typified by influenza or parainfluenza viruses. Less knowledge exists in the case of the virus particles exhibiting cubic symmetry resulting in a compact type of icosahedral virus particle. This is adopted by many viruses including plant, insect and mammalian viruses. As typified by the human adenovirus the icosahedron has been intensively studied and in spite of much probing the exact form of the DNA of this virus still escapes definition. It is located as an internal ‘core’ on which the protein sub-units are arranged along defined radial axes of symmetry forming the capsomeres. The fibre-like antennae with their terminal knobs appear to provide for virus-specified proteins which serve as additional antigens. In addition to these two basic structures there are many other individual variations.

It may well be asked what the past 20 years of study of the structure of viruses as macromolecules has contributed in terms of understanding. A major consequence is the uncovering of the essential unity of the viruses of plants and animals for there is now no sharp line of distinction between these. In spite of the fact that plant viruses are all RNA-containing, whereas roughly half the animal viruses contain RNA and the rest DNA, their morphological resemblances are truly remarkable. That all viruses contain only one form of nucleic acid and not both, marks them out as being fundamentally distinct from all free-living micro- or macro-organisms (Lwow, 1957). Gone is the concept that a virus is a minute bacterium rendered degenerate by intensive parasitism. True that viruses are parasitic and that their ability to multiply depends on their penetration into a host cell but this alone is not unique to viruses. We now use a combination of physical structure including the type of symmetry of the particle, the number of capsomeres belonging to each particle, the type of nucleic acid and the presence or absence of an envelope as the bases for the classification of viruses whether these are plant, bacterial or animal. Such a classification takes no account of the pathological effects engendered by viruses on their hosts.

Much of what has just been said is comparatively well-established and by no means recent knowledge. But the application of refined biochemical techniques to virus particles or fragments is still in its infancy. Biochemical molecular virology is uncovering the nature of the structural proteins including their polypeptide constitution and is adding greatly to the knowledge derived previously from immunological analysis. Thus 7 or 8 polypeptide species have now been identified as virus-coded proteins of the influenza virus (Skehel and Schild, 1971); 4 are glycoproteins including the surface haemagglutinins and neuraminidase enzyme. A new membrane protein has been found and this is associated with the lipid which encloses the ribonucleoprotein. An enzyme—an RNA-dependent, RNA polymerase—is contained within the virus particle and is presumably concerned with the replication of the virus nucleic acid (Influenza Workshop, 1972). This information has yet to be put to definitive use but it may help to define a method of attack by chemicals on those virus constituents not shared by the host cell and thus lead to antiviral chemotherapy. Dr Oxford, working in Canberra, has recently studied the influenza ribonucleic acid polymerase and believes it to be susceptible to chelating agents. Someone, somewhere, must surely break open the problem of a rational chemotherapy of viruses, which still lags and prevents the development of the treatment of virus infections of man.

(b) Virus multiplication and virus genetics

It is now universally accepted that virus replication depends upon virus nucleic acid. Indeed in the case of the bacteriophage, the protein coat remains on the exterior of the bacterial host and only the DNA enters the cell. Animal virus particles enter host cells intact but are rapidly taken apart by uncoating enzymes so that the RNA or DNA is released into the cell. Indeed infection has been successfully accomplished in a number of cases by extracting free nucleic acid. The latter is highly sensitive to destruction by cell nucleases and presumably the virus protein is its chief protector. The cycle of replication initiated by the viral nucleic acid within the cell is a highly complex process and is as yet only poorly understood.

In spite of its close intracellular relationship with the host cell in which it merges, the virus maintains its genetic independence though being subject to variation and error during replication. Spontaneous or induced mutation is occurring all the time but variants will only be detected when they enable the virus to take advantage of selective environmental circumstances. Thus many variant particles perish because they are defective unless, like certain strains of the fowl Rous sarcoma virus, they can borrow facilities from a latent virus present in the same cell. Much studied of recent years are the mutants termed...
temperature-sensitive (ts). These are usually less pathogenic than normal wild viruses. Sabin's attenuated polioviruses thus exhibit the property of restricted multiplication at temperatures in excess of 39° C which suit virulent polioviruses quite well. Deliberate induction of mutation by chemical agents such as fluorouracil and selection by exposure to temperatures which restrict multiplication has led to the development of 'ts' attenuated influenza and respiratory syncytial viruses for use as vaccines. This has been done by Dr. Chanock and others at Bethesda (Wright et al., 1973; Murphy, et al., 1972). However, 'ts' mutants selected by exposure to graded environmental conditions are preferred by some for the preparation of live virus vaccines (Beare and Bynoe, 1969). This is because of the importance of genetic stability in a virus which actually replicates in the host.

In nature and certainly in the laboratory, antigenic variation of some viruses, such as the influenza virus, appears to be the usual method of survival in the face of the selective pressure of host antibodies. A small change in the surface proteins—the haemagglutinin or neuraminidase—will enable the emerging altered virus to resist neutralization by the host's antibody system. Repeated transfer thus results in the occurrence of 'antigenic drift' and this accounts for the small year-by-year variations in the antigens of influenza A and B viruses. But the mechanism whereby the sudden very large antigenic change in the surface proteins occurs every 10 years with influenza A virus is still unknown. It is this genetic variation to a previously unknown virus that brings disaster to our attempts to build up a sound system of prophylaxis with vaccines. In Canberra, biochemical techniques have been used to analyse the haemagglutinins of different influenza virus strains. Polypeptide chains thus finger-printed are compared and possible sources of new combinations glimpsed. Laver and Webster (1972, 1973) have recently shown that the haemagglutinin of the Hong Kong influenza virus variant thus differs chemically from that of the forerunner Asian viruses. Its light chain resembles closely that of an equine influenza virus and it is now suggested that antigenically new influenza viruses which arise at intervals may be produced by genetic interchange between human and animal viruses. Such a mechanism exists in the laboratory as genetic recombination and is used to prepare new combinations of strains. It is Burnet's aphorism that anything which occurs in the laboratory probably occurs in nature that has added weight to this hypothesis.

(c) Changes in the host cell

A bacteriophage particle which injects its nucleic acid into a susceptible bacterium causes one of two processes. In one, the nucleic acid sets about reproducing a swarm of phage particles which ultimately burst the bacterium. Or, the phage DNA enters the DNA ring of the bacterium and is replicated when the latter divides. In this case the bacterium and its progeny are termed lysogenic. Under appropriate circumstances such as UV irradiation the phage nucleic acid is freed and produces a host of phage particles with resultant lysis of the bacterium. Is this a phenomenon peculiar to the bacterial world or do similar events occur with mammalian viruses?

The event most likely to be initiated by entry of a mammalian virus into susceptible cells growing in tissue culture is that the virus will reproduce and the cell will be destroyed. This, however, is only one consequence and there are plenty of instances of virus replication inside host cells which remain unaltered. When tissue cultures are prepared from normal embryonic tissues and carried serially through many generations they ultimately undergo cell transformation. This is a phenomenon of increased capacity for growth, lack of contact-inhibition and change in the number of chromosomes. It can occur in normal cultures in one step if one of the RNA or DNA tumour viruses is added. Thus a third form of virus-cell relationship exists in that the virus transforms the cell but does not itself replicate. The host cells, however, multiply freely and if either they or the original virus are inoculated into an animal host such as a weanling hamster there results a tumour, usually a sarcoma which can be subsequently propagated by grafts.

What then has become of the virus? The current view that a fragment of viral RNA or DNA has become integrated with the cell genome is largely based on immunological work. The transformed or tumour cells develop new specific proteins known as 'T' antigens and these also appear in normal tissue cultures infected by the homologous virus in the usual way. Yet these 'T' antigens can only be detected by tests which employ antisera in the shape of serum from tumourized animals so that they are not structural components of the virus. Probably 'T' antigens are specified by the integrated virus nucleic acid within the nucleus of the host cell. They are certainly specific for the virus concerned whether this is the SV40, polyoma or adenovirus 12.

Arising from the flurry of new work occasioned by study of viruses as carcinogens has come the concept of a virus-precursor built into the nucleus of normal cells. It was work with the RNA leukaemia viruses of avian and murine origin which suggested that leukaemic or lymphomatous viruses were frequently to be found in apparently healthy animals possessing a high leukaemia risk. Known as a C. RNA virus (Bernhard and Guérin, 1968) and termed oncornavirus by American authors, it is suggested
that these single-stranded RNA viruses are transmitted vertically from mother to offspring but that they do not manifest their presence because of the activity of repressor genes. When de-repression occurs the provirus portion of the genome produces a transforming protein responsible for transformation of the cell into a tumour cell. This virogene theory of cancer (Huebner) postulates that ageing, irradiation or carcinogenic agents of any sort act as de-repressors and 'switch-on' the oncogene. The existence of a virus enzyme—RNA-mediated DNA polymerase or reverse transcriptase—has furthered the oncogene theory (Todaro, 1973). Though reverse transcriptases are found in normal cells, those present in tumour viruses are antigenically distinct and yet share relationships with similar agents from different mammalian species. The virus theory of human cancer is certainly beyond the scope of this lecture but it should be abundantly clear by analogy with mammals that at least some human cancers are almost certainly caused by viruses. What has been said about virus-cell relationships should also indicate how tough is the problem of detecting within a tumour cell a virus fragment which is not self-replicating. It seems obvious that the hints and evidences thus far obtained are just a prelude to a remarkable new chapter in the story of human virology.

The pathogenesis of virus diseases

Let us turn from a consideration of the virus at a cellular level to some trends of research upon infection of the whole animal host. The first of these arises from the development of immunology including new work upon the immunoglobulins found in the blood and upon surface secretions and endowed with the properties of antiviral antibodies. But much concern is also being shown to cellular factors concerned in immunity and to the relative importance of cells and of antibodies in the determination of an effective immunity. The observed differences between the effectiveness of immunity induced by live virus vaccines which mimic infection and that provoked by killed or inactivated vaccines are now becoming amenable to analysis. Sometimes the advantage of a live vaccine seems to be related to the local surface immunoglobulin A induced in the secretions of the alimentary or respiratory tracts. But cellular immunity involving the lymphocytes is also concerned even in a superficial condition such as influenza so that the mechanism of immunity is complex. It is still a remarkable fact that the susceptibility or the resistance of the individual human to influenza during an epidemic is not fully understood, and that more work upon vaccines is therefore required. Efforts to evolve and apply safe and effective immunizing agents still involve basic research in spite of the obvious benefits derived from vaccines such as those in use against smallpox, yellow fever and poliomyelitis.

Another facet concerned with the rôle of cellular immunity has been derived from observations on patients with renal transplants treated with immunosuppressive drugs such as cyclophosphamide or antilymphocytic serum. Prolonged immunosuppression appears to enable certain latent viruses to become actively infective. Extensive lung lesions due to cytomegalovirus, the urinary excretion of particles of a hitherto unknown polyoma-like virus (Coleman, Gardiner and Field, 1973) and tumours of a lymphomatous type are all found in such treated patients. Nevertheless natural resistance to viruses, the curious fact of species resistance to viruses not normally found as infecting agents, remains unexplained. Also the relative importance of antibodies, cellular activity and the secretion of interferon in the recovery of a host from infection is still far from obvious.

A new trend is that upon the investigation of possible harmful actions of immunological mechanisms. Such actions are of a varied nature. The first clue that antiviral antibodies may sometimes be harmful came from studies on children in America given inactivated measles vaccine. Upon subsequent exposure to natural measles infection, some children developed fever and a peculiar rash unlike measles. As live measles vaccine does not seem to give rise to this risk, it has been suggested that inactivated vaccine produces antibodies which attach to and sensitize cells to a later exposure to measles virus antigen. A second clue is that derived from experience with inactivated respiratory syncytial (RS) virus vaccine. In the U.S.A. a controlled experiment in which infants were given either inactivated RS or parainfluenza virus vaccines ended during the succeeding RS epidemic season with more instances of RS bronchiolitis in those receiving the homologous vaccine. Chanock of the National Institutes of Health (Chanock et al., 1970) considers that RS infant bronchiolitis occurring between 3 and 9 months of age may be a disease in which maternal antibody of IgG type has sensitized the epithelial cells to subsequent RS virus infection. He thinks that the more usual consequence of RS infection is to induce local IgA at the epithelial surface which blocks any harmful sensitizing action and that the clinical disease is due to a Type 2 or Type 3 allergic reaction in certain individual infants. Gardner in Newcastle disputes this view and has suggested that a Type 1 reaction mediated by local IgE is the explanation of bronchiolitis (Gardner, McQuillin and Court, 1970). This conflict of the experts' views should not obscure the fact that both agree that clinical RS disease is not just the result of cellular epithelial necrosis as in the case of influenza.
Two further instances exist of immunopathological effects in virus infection. A complement-mediated form of cell destruction has been uncovered in some experiments with myxoviruses and even herpes virus (Porter, 1971). Secondly, an immune-complex capable of causing pathological effects such as those of nephritis has been suggested in relation to serum hepatitis B. The discovery of the Australia antigen in the serum of carriers and in patients with acute or chronic liver disease has brought a flood of speculation. Almeida and Waterson suggested some time ago (1969), when they observed clumping of Au particles by rabbit anti-Au-antigen serum, that immune complexes existed in the serum of patients with hepatitis. Lately an unexpected discovery of Au-antigen in the serum and blood vessels of patients with polyarteritis nodosa has raised the concept of damage from serum-virus complexes (Gocke et al., 1970). It is, in my view, too early to form a judgment on this matter largely because the nature of the Au-antigen is still obscure.

Conclusion

It is timely to attempt some remarks on the future. The prospect for the solution of any scientific problem must be unpredictable until initial clues have been obtained. In the case of the outstanding problems of human virology which have been described there are promising pointers yet no one can foretell when solutions will be obtained. Thus, attempts to formulate antiviral chemotherapy have been made repeatedly for more than 20 years with relatively slight success. Now with the better knowledge of the biochemical basis of virus multiplication more rapid progress seems likely. But chemotherapy or chemoprophylaxis will not come about by staring at patients or testing rows of synthetic compounds even though serendipity can be fruitful. Research must be pursued at a cellular or intracellular level and this is one reason why molecular biochemistry’s alliance with virology must be applauded.

Consider next the relationship between viruses and tumours. The hypothesis of the oncogene has been followed by a hectic pursuit of virus-specific nucleic acid polymerases. Study of these reverse transcriptases requires highly complex techniques and progress must therefore be slow. At the moment it seems possible that the transcriptases of the oncogenic viruses are recognizably dissimilar from those of normal cells. More cannot be said except that the theory of the virus as a cause of some human cancers seems to have gained ground steadily over the past 10 years. The ups and downs of this aspect of cancer research have, however, been considerable in the past and the prophet of the future needs must be cautious. Meanwhile this problem against demands basic research at a cellular level and I for one do not share the views of those who question the development of molecular virology and its possible contribution in the future.

What then of the outstanding problems of virology in relation to human disease? Chronic pathological processes, particularly of the nervous system, are now in the limelight. Clinicians are at last realizing that virology is not just a branch of bacteriology and that viruses are not just the cause of acute self-limited infections. But the reasons for the adoption by the virus of a chronic form of parasitism and the failure of the host to eliminate the virus particles furnish problems which need a great deal of research. Here immunological techniques and animal models are called for in addition to the human patient. The team which will investigate viral pathology of this type must include some who have experience and knowledge of the human patient. But the techniques are those of the laboratory and the team must include those with knowledge of ultrastructure and of immunology. I hold no brief for the lone research worker in this field nor for the scientist bereft of assistance from the medical virologist.

I hope this brief outline of the way ahead may prove an exciting prospect to those young men and women whose careers are undecided. Virology has been an exciting discipline for me and I believe it should continue to be so for others for many years yet. There is much talk of the present as the golden age of virology. I venture to prophesy that diamonds, not gold, lie ahead.

References


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