NATURAL HISTORY
OF
INFECTIOUS DISEASE

BY

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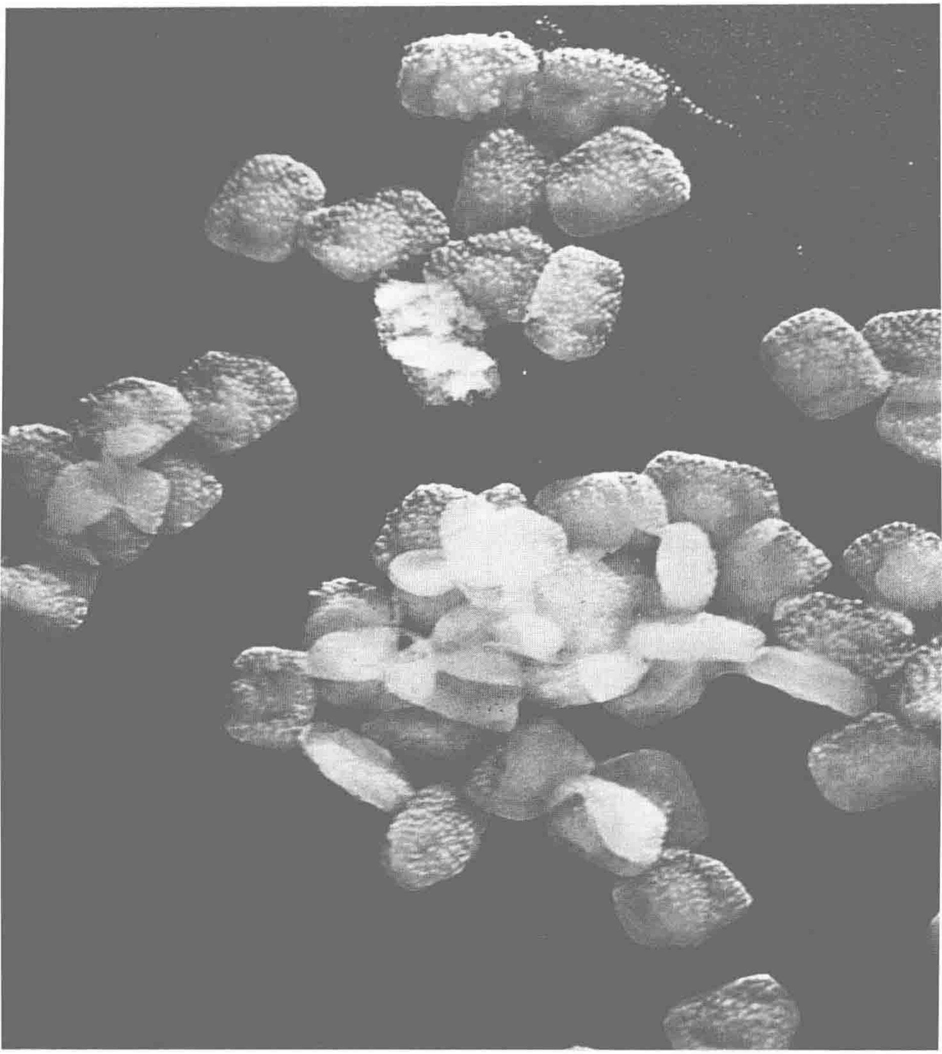

VACCINIA VIRUS

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CONTENTS

PART IV

THE NATURAL HISTORY OF INFECTIOUS DISEASE

PART V

SOME IMPORTANT INFECTIOUS DISEASES

ILLUSTRATIONS

Part I

BIOLOGICAL CONSIDERATIONS

CHAPTER I

THE ECOLOGICAL POINT OF VIEW

Infectious disease is, and always has been, part of the everyday experience of life. In every generation men of affairs have had to cope as best they could with the practical problems it presents, while priests, philosophers, and, later, scientists have had perhaps the harder task of interpreting the significance of such disease in accordance with the intellectual outlook of their time. Over most of the historical period, the human attitude to epidemics and the other aspects of infectious disease was a curious mixture of erroneous theory with a good deal of useful common sense. On the practical side, we must remember that the contagiousness of some of the more easily recognized diseases like plague and leprosy was well understood in the Middle Ages, and logically planned measures to prevent or minimize epidemics were attempted. The institution of quarantine for travellers from infected regions by the Venetians in 1403 may be instanced, while a general recognition of the association of disease with civic filth and personal uncleanliness goes back to classical times.

Theoretical ideas took some fantastic forms, but after the time of Hippocrates there was nearly always evident a desire to replace the too simple explanation of disease as divine vengeance for wrongdoing by some more immediate cause. Infection seemed obviously to pass from person to person in the air, and it was a natural association of ideas to think of the spread of infection as analogous to the diffusion into the air of unpleasant smells from septic wounds or dead bodies. From the earliest times, putrefaction, especially of unburied human corpses, was regarded as likely to breed disease. In the early nineteenth century, bad drains, that is, smelly drains, were universally blamed for typhoid fever and diphtheria. Even as late as 1890, well-informed epidemiologists considered that epidemics of plague, influenza or yellow fever might be initiated by the diffusion of gaseous material from poisons in the soil, usually of putrefactive origin. They knew that a further generation of infective material in the bodies of those initially infected must occur and be responsible for spread of the epidemic, but they looked for the initiating cause of the epidemic in peculiarities of soil and weather.

With the coming of Pasteur and Koch, the mystery of infectious disease seemed to be swept away for ever. 'Fluxes, agues, botches and boils', not to mention the major pestilences, were all due to the attack of bacteria or similar micro-organisms on the body. The new science of bacteriology provided a great impetus to the process of cleaning up the conditions of human existence which had begun, in England at least, a few decades earlier. A rational basis was now available for the demands for pure water supply, sewerage schemes, pure food and milk regulations, prevention of overcrowding, and so forth. Medical, and particularly surgical techniques were revolutionized by antiseptic and aseptic methods. Typhoid fever disappeared, and infantile mortality rapidly declined, surgeons freed from the fear of sepsis flourished, and a few economically vital areas of the tropics were cleared of yellow fever and malaria. All these triumphs, and they were triumphs, received the publicity they deserved. Medical research, and especially bacteriological research, became an eminently worthy occupation.

Over the period of the second World War one can almost say that most of the remaining practical problems of dealing with infectious disease were solved. Penicillin was discovered and subsequently half a dozen other potent antibiotics to deal with those bacteria untouched by penicillin. In 1951, it is hardly an exaggeration to say that no previously healthy child or adult need die of any bacterial or protozoal infection if he can reach an adequately equipped hospital before the infection has irreparably damaged his tissues. New insecticides and new methods of using them have made it feasible to eradicate most of the insect-borne diseases even in relatively undeveloped countries. Malaria was banished temporarily at least from continental United States in 1950 and typhus fever, thanks to a combination of preventive vaccination and improved measures against louse infestation, played no significant part in the War.

In many ways one can think of the middle of the twentieth century as the end of one of the most important social revolutions in history, the virtual elimination of infectious disease as a significant factor in social life. If we could be assured of peace we could feel confident that over progressively greater regions of the earth we should see a swift reduction in mortality, and the relegation of infectious disease to the relatively trivial illnesses which are all that most families in advanced communities know from direct experience.

Along with this development of practical measures of preventing and curing infectious disease, there has gone a steadily increasing interest in the intrinsic characteristics of the micro-organisms responsible for disease. It might almost be said that in the last twenty or thirty years the centre of interest in bacteriology has moved from the problems of infectious disease to the use of micro-organisms in the study of the fundamental chemical problems of living substance. It is significant of the change in outlook that the older generation of bacteriologists who were mostly trained as medical men has now almost been replaced by workers trained primarily as biochemists.

But other biological sciences have moved forward as well as biochemistry and, although workers in such fields are fewer in number, there are many who are interested in what may be called the ecological aspects of infectious disease. In a broad way one can divide the biological sciences into two groups. There are those that are concerned with the structure and functioning of the living organism and of its component parts, anatomy, physiology, cytology, biochemistry and so on. On the other hand, there are those sciences which deal with the interaction of organisms with their environment and especially with other organisms whether of their own or different species in that environment. Ecology is a broad term covering such an approach to the problems of animals, plants and micro-organisms, and in the human sphere we can include the social sciences under the same heading. Next to the recognition that bacteria provide in almost a diagrammatic form the essential chemical processes of living matter, the application of the ecological point of view to the problems of infectious disease probably represents the most important change of attitude by microbiologists in the past twenty or thirty years.

Since the eighteenth century, at least, there have always been educated men of some leisure with a natural interest in the activities of animals and plants. Many of these amateur naturalists, from Izaak Walton and Gilbert White onward, have written about the way animals make a living. The habits of birds in feeding, courting and nesting have attracted the interests of many. Others have spent years unravelling the life history of insects, especially the miniature civilizations of the ants, bees and termites. In more recent years, this essentially amateur type of observer has been supplemented by the professional biologist, whose more systematic investigations in the field once known as nature study have raised its dignity to the science of ecology. As the form of the word suggests, ecology is the study of the economics of living organisms. Animal ecology deals with the activity of animals as individuals and as species, their mode of feeding and of reproduction, the environmental conditions necessary for their well-being, and the enemies with which they have to contend. The combined action of such factors determines how numerous a species will be at any particular time and place. Sometimes inconspicuous changes in the environment of a species may produce extreme changes in its numbers, and in practice most ecological investigations are undertaken to elucidate the excessive abundance or undue scarcity of some economically important animal. Like most, perhaps all sciences, ecology has developed in response to practical human needs. On the one hand, there are countless pests which, when their numbers are excessive cause great economic loss from damage to growing crops, domestic animals or stored food products. On the other hand, there are the economically important wild animals, the fur-bearing rodents and carnivores of subarctic regions, the edible fish of the North Sea, the whales of the Antarctic, and so on, where the problem is to avoid undue scarcity or extinction of the species. If the pests are to be controlled or the valuable species saved from extermination, every detail of their life histories, their physical environments, and of the numbers and habits of their enemies may be necessary. It is the task of the trained ecologist to provide this knowledge and to show how it can be applied to the desired end.

Every animal species reproduces its kind at a far greater rate than would be necessary to maintain its numbers if death occurred only as a result of old age or accident. In nature, of course, limiting factors are always present, and the maintenance of the numbers of a species can be regarded as the result of conflict between two opposing forces, the 'population pressure' of the species, the constant production of more young than can hope to survive, and the equally constant destruction of individuals by physical calamities, frosts, floods and the like, predatory and parasitic animal enemies and infectious disease. Except for some large, slowly breeding animals, the reproductive potentialities of most species are so great that it needs only a surprisingly short time for a vast increase in numbers to occur following some change in the environment unusually favourable to the species concerned. In most practical problems, this capacity for rapid multiplication can be taken for granted, and attention need be focused only on the two principal factors which diminish or limit the numbers of any species—the available food supply and the activity of enemies. The animal enemies of a species include those which capture and devour their prey (predators) and those smaller forms which live in or on the tissues of their host (parasites); and not infrequently there are enemies whose harmful activities are intermediate between those of predator and parasite —the blood-sucking insects and vampire bats for example. All these activities of enemies, however, have the same object, to obtain food for their own requirements from the tissues of their victims. Put concisely, the two essentials for survival are that an animal should find enough to eat and avoid being eaten itself. Food thus becomes the central problem of ecology.

Every animal needs for its nutrition some form of protein which can be used to build up its tissues, and carbohydrate or fat to provide energy for its activities. In the body the chemical form of these substances can be modified, but the essential 'building stones', amino-acids and simple carbohydrates, must be obtained from without. Only the green plant can synthesize these substances from inorganic materials, and all animals are primarily dependent on plants for their nutrition. Probably more than half the species of animals and the vast majority of individuals feed directly on plants or their products. There is an infinite variety in the methods of such feeding. The single-celled protozoa engulf minute green algae, fish and molluscs browse on seaweed, insects and humming birds seek honey in flowers; there are eaters of seeds and fruit, leaves, bark and roots; insect larvae and termites tunnel through wood, using it as food in the process, and there are multitudes of insects which exist by sucking the juices of plants. A few species of animal, protozoa and certain corals, have dispensed with the necessity of devouring plant material by incorporating small green algae in their tissues and utilizing the food material synthesized by these primitive plants.

All these plant-feeding animals by their digestive processes break down the plant substances to simpler molecules, and discarding waste materials build these up into their own proteins and fats. In doing so they provide for other creatures a more concentrated and more readily utilized store of food.

Nearly every animal is liable to become the prey of some predatory carnivore, and with the exception of the largest carnivores, this holds irrespective of whether the animal itself feeds on plants or on other animals. For every animal species one can trace back its food supply through one or more stages to the ultimate source in plant tissues. To take an unusually complicated example, a shark feeds on large fish which in most cases capture smaller fish. These probably find their main food supply in small crustaceans which feed on the protozoa of the surface waters. The protozoa live on microscopic green algae, the unicellular plant organisms which are the final source of food for most marine animals. Such a sequence of organisms, each feeding on the one beneath it, is referred to as a food-chain. Amongst land animals the food chains are usually composed of fewer links than amongst the larger marine forms. A lion feeds on plant tissues at only one remove, since large herbivorous mammals are its usual prey. A longer chain leads from the small, but very numerous insects, aphis, plant lice, scale insects and so on, which suck plant juices. These are preyed on by the larvae of ladybird beetles, which may provide food for birds either directly or after being eaten by spiders. Owls and hawks, by feeding on the smaller birds, complete the chain.

In all the series we have mentioned so far, the animal which eats is larger than that eaten. At the end of each food chain we find the larger carnivores, eagle and owl, wolf and lion, killer whale and shark, along with a few herbivores like the elephant, which, by their size or for some other reason, are immune from attack. Such animals have no visible enemies in nature, but they are just as exposed to the attacks of parasites as smaller types. The tiger may be the lord of the jungle, but its lungs may be riddled with parasitic worms.

The parasitic mode of life is essentially similar to that of the predatory carnivores. It is just another method of obtaining food from the tissues of living animals, and it is sometimes not easy to decide whether a given form is or is not a parasite. In general, a parasite may be defined as an organism smaller and less highly differentiated than its host, which lives on the skin or within the tissues or body cavities and gains its nourishment at the expense of the host's living substance. Although at present we are concerned with the means by which animals gain their food, we can class all the internal parasites together. The micro-organisms of disease, just as much as parasitic worms, are using the tissues of their host simply as a source of the food they require for growth and multiplication.

As an example of the way in which this complex interaction of species feeding on and forming the prey of other organisms is reflected in the varying numbers of the species concerned, we may describe one of the first and most striking successes of applied ecology. Soon after orange growing had become an important industry in California, serious losses began to occur through the spread of a scale insect. The trees were covered with little white cushions built up by the insects as a protective covering beneath which they sucked the sap of the orange trees. It was soon found that the pest was not a native American insect, but an importation from Australia. There it normally lives on the native acacias, and when it spreads to orange trees does no particular damage. The difference between the behaviour of the insect in Australia and in California was not due to climate, but to the fact that in its native home the cushion scale insect is the chief food supply of a ladybird. The two insects automatically control each other's numbers. If the scale insect is particularly plentiful, the ladybird larvae find an abundant food supply and the beetles in their turn become more plentiful. An excessive number of ladybirds will so diminish the population of scale insects that there will be insufficient food for the next generation, and therefore fewer ladybirds. On the whole, a balance will be reached with such a population of each species that the destruction by enemies is approximately equal to the increase in numbers allowed by the available food supplies.

In California there were no carnivorous insects adapted like