in or near the polar regions where glaciation is the predominating evidence of change of climate. What changes should we expect to see in other regions of the world? Changes of temperature are difficult to recognise geologically, except in polar or desert regions, but changing precipitation leaves a very clear record in the strand lines of lakes and inland seas. Now it is generally recognised that during the ice age there were great variations in the levels of lakes, so much so that the term pluvial periods has been introduced to specify these periods. Is there any relationship between these pluvial periods and the ice ages? In the 'Great Basin' in North America there is clear evidence of the pluvial periods. According to Gilbert and Russell, both Lake Bonneville and Lake Lahontan show two periods of high level between which both lakes were completely dried out and desiccated. They also found clear evidence of glaciers entering the enlarged lakes, showing that one at least of the maximum epochs of the lakes coincided with one of the North American ice ages. The pluvial periods have also left clear traces in equatorial Africa, and here again the evidence points to two main pluvial periods, the first of which, according to Wayland (see *NATURE*, Aug. 17, 1929, p. 279), corresponds to the Gunz-Mindel Ice Age and the second to the Riss-Würm Ice Age. Thus in both North America and in Africa there have been during the Pleistocene Period two main pluvial periods, while in polar regions there have been four ice ages.

Whether the theory of the cause of the interglacial periods which I have sketched here will prove to be correct or not can only be determined after years of research, and, in discussing it, account must be taken of possible movements of land masses and possible shifts of the poles. I do not propose to go into any further details here, but will simply direct attention to several consequences of the theory which should be touchstones for testing it:

(a) The four glacial ages occurred during periods

of relatively high temperature in all parts of the world.

(b) There are two kinds of interglacial periods: (1) warm interglacial periods which occur between the two members of each pair of glacial periods; (2) cold interglacial periods corresponding to the interval between the occurrence of the pairs of glacial periods.

(c) Each pair of glacial periods, with the intervening warm interglacial period, coincides with a pluvial period in unglaciated regions.

RECENT CHANGES IN CLIMATE.

There has been much controversy regarding climatic changes in historical times. It is impossible for me to go into the details of this controversy, but I think I may fairly sum up the discussion by saying that there is little evidence for any appreciable change in temperature, but that there is quite a mass of evidence for moderate changes in the amount of rainfall. It is clear that the historical period is much too short to show any appreciable part of the large but slow changes which give rise to the main changes of climate shown in the geological record and of which the ice age is the last example. These changes probably required 20 or 30 per cent in the change of solar radiation. Any change in the historical period must have been of the order of only a few per cent, and probably took the form of minor fluctuations on a more general change.

Now I have tried to show that the effect of changes in solar radiation are chiefly counterbalanced by a change in the general circulation of the atmosphere and increased cloud and precipitation rather than by large changes in the temperature. It is not surprising, therefore, that what fluctuations there have been are shown chiefly by fluctuations in rainfall; the best evidence of which is seen in the changed level of lakes without efflux, the changed boundaries of deserts, and the relics of old cultivation in places where now cultivation is impossible.

Dog Distemper and Immunisation.

By P. P. LAIDLAW, F.R.S.

SOME seven years ago the *Field Distemper Fund* was inaugurated with the object of encouraging the study of dog distemper, in the hope that the ravages of this disorder might be mitigated through the discovery of some preventive measure or some satisfactory method of treatment. The *Field Distemper Council*, which body administers the *Field Distemper Fund*, joined forces with the *Medical Research Council* for the purpose of this study, and a scientific committee, composed of veterinary and medical men, was formed to supervise the research work. The *Medical Research Council* is interested in dog distemper as it is an example of an acute infectious fever, comparable in many respects to such diseases as influenza or measles in man, and it was hoped that the study of the canine fever would ultimately lead to a better understanding of such infectious fevers in man.

The highly infectious nature of distemper rendered the study somewhat difficult, for it was necessary to take elaborate precautions throughout the investigation in order to guard against accidental spread of the disease. New buildings were constructed for the work and dogs were bred, in the strictest possible isolation, for the purposes of experiment. Progress was thus inevitably slow, but it is now clear that without the special equipment and in the absence of the rigid precautions against accidental infection, it is highly probable that little progress would have been made.

The demonstration of the fact that ferrets were very susceptible to dog distemper was of great assistance to the work, for it was found to be possible to experiment in the first instance with this species, which is relatively easy to maintain in close confinement and strict isolation, and reserve the specially

bred dogs for crucial experiments. The facts disclosed in the study of the disease in ferrets have been shown to be applicable to the disease in dogs with only minor modifications.

At the time the work for the *Field Fund* was commenced, the nature of the infectious agent in dog distemper was not firmly established. Carré, in 1905, came to the conclusion that the disease was caused by a filterable virus. He quoted experiments to show that the contagium would pass through the pores of filters specially designed to hold back all ordinary bacteria, and he found that the disease could be transmitted with material in which no structures resembling bacteria could be detected under the microscope and from which no bacterial cultures could be secured. Carré's view did not meet with general acceptance, and from time to time various visible bacteria, which were regarded as causal organisms, were secured from distemper cases. That infection with ordinary bacteria did occur very frequently in distemper cases was undoubted, but it was by no means clear which of the several bacteria recovered from diseased animals should be regarded as the primary cause of the disorder and which the secondary, or if, under the view put forward by Carré, all the visible bacteria were really secondary infective agents and the true contagium was an ultramicroscopic virus.

The workers for the *Field Fund* confirmed Carré's findings in all essential particulars and showed that the disease could be transmitted, at will, by the blood and tissues of distemper cases through an indefinite series of animals. The infective material appeared to be sterile in all the usual laboratory culture media and no bacteria could be demonstrated by microscopic examination. Further, the infective principle was shown to pass through bacterial filters of standard type and proven quality. It thus seems established that dog distemper is primarily a virus disease and that all the bacteria which can be recovered from distemper cases are really secondary invaders of damaged tissue. It was further obvious that preventive measures should be directed against the virus infection in the hope that, if this could be eliminated, the secondary invading organisms would be deprived of their aggressive ally and rendered almost, if not quite, impotent.

It was found that distemper virus could be inactivated or killed in a number of different ways and that, provided the treatment to which the virus was submitted was not too drastic, the inactivated virus formed an efficient vaccine. That is to say, a large dose of inactivated virus could be injected into an animal with complete impunity and, after the lapse of some days, the recipient of the vaccine developed a resistance to injections of fresh living virus. Supplies of virus cannot be secured by artificial culture methods, as is the case with ordinary bacteria, and recourse was therefore made to the tissues of distemper animals as a source of crude virus. The lymph glands, spleen, and liver of distemper animals nearly always have a high virus content and they can be converted into an efficient

vaccine, without much difficulty, by means of small doses of formaldehyde. It was found to be possible to immunise more than 90 per cent of ferrets by giving them a single injection of vaccine made from distemper ferret tissue. Similarly, it was found to be possible to render dogs resistant by means of a single dose of vaccine made from tissues of a distemper dog. The resistant state which develops in a dog or ferret after the injection of vaccine is converted into a solid and durable immunity by the injection of living virus. Animals so treated have been given massive doses of distemper virus and they remained unaffected; they have been deliberately placed in contact with severe cases of natural distemper, complicated by secondary infections and without complications, and they have not developed the disease.

After the method had been shown to be almost uniformly successful under experimental conditions, the method was extended to the field and several hundreds of foxhounds and other breeds of dogs were first vaccinated and then given a small dose of living virus. It was hoped that this procedure would give as solid and as durable an immunity as that which follows a recovery from the natural disorder and yet be comparatively free from risks. It was realised that the injection of living virus could never be made absolutely safe, but the immunity which follows recovery from the natural infection, however mild, is so firm and so durable that a final dose of living virus should guarantee real immunity in the vast majority of instances. The resistance set up by vaccine alone, though very definite and significant, was scarcely great enough to be called immunity, and it was doubtful if it would, by itself, render a dog immune for life. The results of this extended field trial were satisfactory in that the great majority of the hounds and dogs came through the immunisation process with no trouble and afterwards proved to be immune to epizootic distemper, which caused severe illness and even death in their unvaccinated companions. In a small percentage of cases the living virus caused a severe reaction in the vaccinated dog, but this was usually of short duration and was followed by complete recovery. In less than one per cent of cases death followed the administration of the virus. The production of the prophylactic has now been undertaken by a commercial firm in Great Britain and by another in the United States of America, and several thousand doses have been issued.

It is not possible to pass any final judgment on the method at the present time. It is clear that the use of living virus carries with it some risk, for its inoculation causes, even in the vaccinated dog, a considerable strain on bodily health, and unless the recipient is free from all forms of infection grave harm may ensue. It is also necessary to remember that the immunisation against the virus disease is no guarantee against infection by bacteria, which may cause bronchitis, pneumonia, gastro-enteritis, and so on, but on the other hand, immunisation should diminish the incidence of these diseases, for it seems clear that the virus frequently weakens the dog's resistance and thus assists bacterial invasion.

Immunisation should prevent, in large measure, the epizootic disease which causes such heavy losses year by year in the canine population.

It may be noted here that this vaccination against distemper is merely a special case of protection against a virus disease by means of inactivated or dead virus. Very similar results have been recorded recently in other diseases such as rabies, rinderpest, fowl plague, and foot-and-mouth disease. In the case of foot-and-mouth disease the matter is complex, for it is now clear that there are at least three strains of virus causing this disorder, and immunity to one strain does not carry with it immunity

to either of the others. So far as information goes, there appears to be only one strain of distemper virus, and a dog or ferret which is solidly immune to a virus from one source is immune to strains from other sources.

The study of distemper has not so far proved illuminating as regards the infectious fevers of man. Vaccines made from homologous tissues are clearly not available in the case of man, and yet the hope is raised that if only artificial cultures could be secured, we might make from them vaccines which would do much to minimise the disharmonies produced by the infectious fevers.

Obituary.

PROF. CHARLES CHILTON.

DR. CHARLES CHILTON, whose death on Oct. 25 is reported from Christchurch, New Zealand, had a career which was in several respects noteworthy. He overcame a physical handicap that might have excused a somewhat passive attitude to life, and he practised in turn three different professions without failing of success in any of them.

Chilton was born at Leominster, Herefordshire, in 1860 and was taken to New Zealand as a child. In his boyhood an accident led to the loss of a leg and incapacitated him from following his father's occupation of farming. It was on this account that he became a student at Canterbury College, where he studied natural science and came under the influence of Capt. Hutton and Sir Julius von Haast, afterwards graduating with honours in zoology. He was a schoolmaster for some fifteen years, first at Christchurch and later at Port Chalmers, where he became headmaster of the High School. He found, however, that the demands of the teaching profession left little opportunity for the pursuit of his favourite studies in zoology, and in 1895, when already approaching middle age, he did what few men would have ventured to do; he resigned his position and came back to Great Britain to enter as a medical student at Edinburgh. His stay in Edinburgh was punctuated with medals and scholarships, and in 1898, after a period as house surgeon in the ophthalmic ward of the Royal Infirmary of that city, he travelled on the Continent, studying diseases of the eye at Heidelberg and Vienna, and returned to Christchurch, where he set up as an ophthalmic surgeon.

All this time Chilton had been giving his spare hours to zoology and had published a series of important papers on the Crustacea. When the late Prof. Dendy received a year's leave of absence from his chair at Christchurch, it was natural that Chilton should be appointed to take his place. Dendy, however, did not return, for during his absence he received a call to King's College, London, and Chilton became professor of biology in Canterbury College. He at once made his mark as a teacher and also as an investigator, although the administrative side of academic life absorbed, as it always does, more and more of the time that

should have been given to research. In 1921 he was appointed rector of his college, a position which he held until the end of 1927, when he had to resign following a breakdown of health due to overwork. Recent letters spoke of his health as completely restored, and his death after a few days' illness of pneumonia was unexpected.

Chilton had a high sense of the scientific man's duty to the community in which he lived, and although he never sought municipal honours, he was prominent in the affairs of his city and province, taking the lead in many movements relating especially to education and the public health. He revisited Great Britain in 1912 as one of the representatives of New Zealand at the Congress of Universities of the Empire, renewing old friendships in scientific and medical circles and receiving the honorary degree of LL.D. from the University of Aberdeen. A heavy blow fell on him when his only son was killed at Gallipoli.

Living in a country of which the invertebrate fauna is still very imperfectly explored, Chilton took the view that the most immediate need of biological research was the thorough exploration of this fauna and the study of its ecological and geographical relations. He early specialised on the Crustacea, and most of his published work refers to this group. In 1891 he published, in the *Records of the Australian Museum*, a paper on "A New and Peculiar Freshwater Isopod from Mount Kosciusko" in New South Wales. This was *Phreatoicus australis*, the first fully described member of a new sub-order now known to contain a considerable number of species in the freshwaters of Australia, Tasmania, and New Zealand. The more recent discovery of a species at the Cape has afforded striking additional evidence of faunal affinity between the South African and Australasian regions. Chilton, as a result of his detailed study of the structure of *Phreatoicus*, pointed out "that the group must be of very considerable antiquity", and thirty-five years later he had the good fortune to confirm his own prediction by describing a fossil *Phreatoicus* from the Triassic rocks of New South Wales.

Another subject to which Chilton gave much attention was the fauna, and especially the Crustacea, of subterranean waters. His memoir on the