THE "MICHAEL SARS" NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910.

IN the month of August last year, Sir John Murray approached me with the liberal offer of defraying the expenses of a deep-sea expedition to the Atlantic Ocean, provided the Norwegian Government were willing to lend their research-vessel, *Michael Sars*, for the purpose. Sir John Murray wished to ascertain whether the appliances and instruments used by the *Michael Sars* for her work in the Norwegian Seas would yield new information in the Atlantic. It was, besides, considered desirable to examine parts of the Atlantic that had previously been only very slightly explored. The Norwegian Government at once signified its willingness to accept this proposal, and I accordingly employed the past winter in making preparations for the expedition, assisted by the captain of the vessel, Mr. Thor Iversen, Prof. H. H. Gran, who agreed to lead the investigation of phytoplankton, and Mr. Helland Hansen, who took charge of the hydrographical researches. For my own part, I decided to cooperate with Mr. E. Koefoed, and to devote myself especially to zooplankton and the study of the bottom-fauna.

The expedition left Bergen at the end of March, arrived at Plymouth—where it was joined by Sir John Murray—and then followed the coasts of Europe and Africa down to Cape Bogador, carrying out special investigations in the Bay of Biscay, the Bay of Cadiz, and the waters between the Canary Islands and Africa—thirty-four stations in all. It next undertook a section into the Sargasso Sea, and after touching at the Azores, proceeded right across the Atlantic to St. John's, Newfoundland (forty stations). From there a section was taken to the south coast of Ireland (twenty-two stations), and, finally, we concluded our investigations by examining the waters between Scotland and Rockall and between Scotland and the Faroes—that is to say, north and south of the Wyville Thomson ridge—so as to study the influence exerted by the Atlantic Ocean upon the Norwegian Sea. The route of the expedition will be seen on the accompanying sketch (Fig. 1).

During this cruise we endeavoured, so far as time permitted, to undertake hydrographical and plankton investigations simultaneously, and we further carried out a considerable number of hauls with the trawl.

The large number of observations and specimens thus secured can, naturally, not be fittingly described before being systematically studied, and it is accordingly only possible as yet to furnish information regarding their nature and extent.

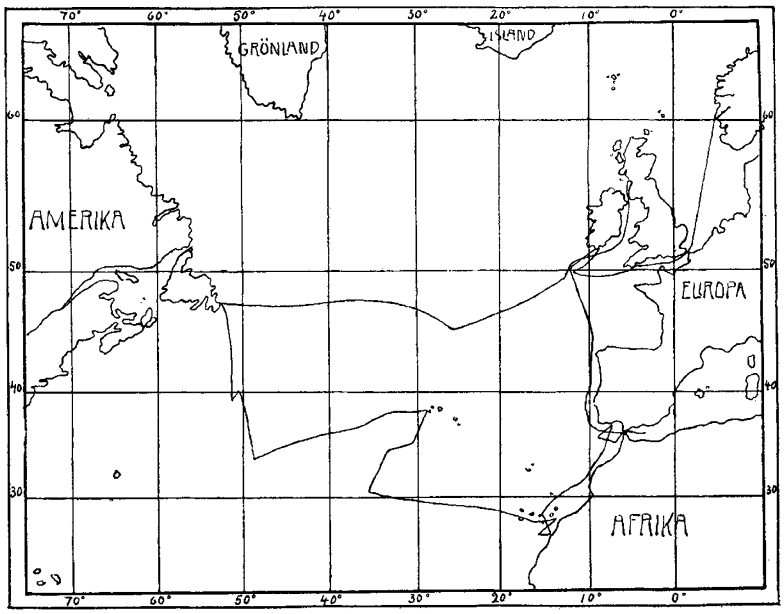

FIG. 1.

HYDROGRAPHICAL INVESTIGATIONS.

Hydrographical investigations have been carried out at about 110 stations. The temperature readings were taken with Richter's reversing thermometer and Nansen's thermometer, while the water-samples were collected by means of Ekman's water-bottle and the Petterson-Nansen isolated water-bottle. At most of the stations the temperatures have been recorded by two thermometers simultaneously at each depth, no fewer than 519 simultaneous readings being taken with the same two thermometers. The corrected temperatures gave an average difference of 0·01° Centigrade.

The difference between the two thermometers was:—

In 168 cases	0·00°
In 231 ,, ...	0·01°
In 84 ,, ...	0·02°
In 36 ,, ...	0·03° or over.

A fair number of simultaneous observations have been made with the reversing thermometer and Nansen's thermometer in the isolated water-bottle, with the view of observing the adiabatic effect by means of the difference in pressure. Besides the temperature readings, we have taken water-samples from all depths to determine the salinity and specific gravity, and we have endeavoured to get an exactitude in the determinations of salinity of 0·01–0·02 per mille, and in the density *in situ* an exactitude of 1–2 in the fifth place of decimals. On these lines the investigations have been carried out along the whole route of the expedition. We have, further, procured about 100 large water-samples from different stations and depths, for the purpose of determining the quantitative occurrence of nitrogenous substances, particularly ammonia.

The determinations from the deepest layers (down to 4950 metres) have given very uniform results, with a temperature of 2·48 C. It has been found that there is a very faint increase of temperature near the bottom at great depths, due, possibly, to the conduction of heat from the interior of the earth or a radium effect. In the upper layers conditions have varied considerably at times, especially in the neighbourhood of the Gulf Stream area and in the western portion of the North Atlantic. Here our investigations furnish apparently a number of new and interesting results, which, however, it is impossible to do more than allude to before the water-samples have been thoroughly examined.

Surface temperatures have been recorded every hour during nearly the whole cruise, while every two hours a water-sample has been taken from the surface with particulars of the different meteorological conditions (wind, barometer, temperature of the air, humidity, and cloudiness). Altogether we have about 2500 water-samples and about 3000 temperature readings.

Several series of direct-current measurements have been made with Ekman's propeller current measurer. In the Straits of Gibraltar the current was so strong that we encountered no small difficulty in regard to anchoring. However, we succeeded in the course of a day in obtaining altogether seventy good measurements from eight different depths between the surface and the bottom. There were considerable tidal fluctuations both in the west-going surface current and in the deep east-going current; simultaneously with the fluctuations in the strength of the current the boundary between the two streams shifted upwards and downwards, as clearly appears from repeated series of temperatures and water-samples. The boundary lay at a depth between 50 and 100 fathoms below the surface. Velocities of four knots or

more were on several occasions recorded in both the surface current and the undercurrent; in the majority of cases, however, the velocity varied between 1 and 2½ knots.

On the slope south of the Azores the *Michael Sars* was anchored in 500 fathoms. Here about ninety current-measurements were made at different depths. In the deep sea between the Azores and the Canary Islands a series

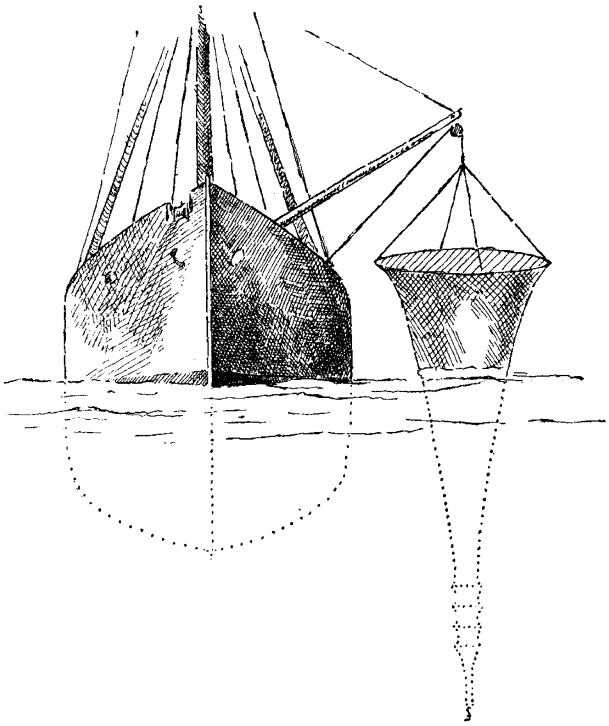

FIG. 2.

was taken right down to 2000 metres, from the vessel while under slow, steady drift, with one of the large tow-nets out as a drift-anchor. These measurements also show considerable fluctuations, which are apparently connected with tides. Similar investigations with modern methods have never been undertaken before either in deep water or in the Straits of Gibraltar.

A number of measurements of light were also made in the ocean south and west of the Azores. Mr. Helland Hansen has constructed a new photometer which worked well; he determined the quantity of light by the aid of panchromatic plates with and without gelatine colour filters. The investigations showed a great influence of light rays at 100 metres, red being the weaker, and blue and ultra-violet rays the strongest; at 500 metres blue and ultra-violet rays were still found, and even at 1000 metres the influence of the ultra-violet rays was clearly evident. No trace of light could be noticed on the plates at 1700 metres, after an exposure of two hours at noon with a clear sky.

PHYTOPLANKTON.

Vertical hauls have been undertaken at various depths, at fully forty stations, with a fine-meshed Nansen closing-net, our object being to collect material for studying the vertical and horizontal distribution of peridinæ and diatoms in the Atlantic Ocean. We specially aimed at obtaining material for comparing the plankton of the coast-banks with plankton from purely oceanic waters, as also for comparing subtropical and boreal conditions of existence. The coast-banks off Ireland, Cadiz Bay, the west coast of Africa, and the Newfoundland banks have a characteristic flora which is sharply marked off from the oceanic flora, rich in species but poor in individuals, which is met with in the central parts of the Atlantic Ocean, especially the Sargasso Sea south of the Azores.

Largely owing to Lohmann's interesting researches in the Mediterranean, we arranged to devote a considerable part of our work to the study of those organisms, especially Coccolithophoridæ and the naked flagellates, which pass through even the finest silk net. These organisms have been partly collected by filtering sea-water through sand filters and partly by employing a large centrifuge driven by a small steam winch. Altogether we have employed the centrifuge in the case of about sixty of these water-samples; and, by means of a suitable contrivance, Prof. Gran was able to examine these samples on board in their living state, both in regard to quality and quantity.

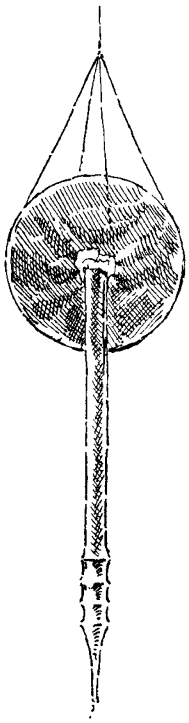

FIG. 3.

Examination showed a large number of new forms, partly belonging to quite new types, which will be described by Prof. Gran. In the central oceanic parts of the Atlantic Ocean these small organisms were found to occur in numerous forms and in such large quantities that they exceed in volume the plants obtained through the medium of the silk nets. In the neighbourhood of the European coast-banks the number of species was far smaller, but the quantity of individuals was particularly large. Thus we secured in a single sample more than 200,000 individuals per litre of one species alone. On the coast-banks off Newfoundland and off Ireland the peridinæ far exceeded in volume the Coccolithophoridæ.

Altogether the samples from the more northerly waters show a greater quantity of plants than the subtropical portion of the ocean. The material will likewise furnish information with regard to the distribution of phytoplankton in relation to depth. In the more northerly waters its range is limited to a thinner, less deep-reaching layer than in the more southern portion of the area of investigations.

ZOOPLANKTON.

For the study of smaller plankton animals, of the size of copepods, for instance, we employ a vertical closing-net, one metre in diameter, with rather coarser silk. With this we took samples at various depths and at many stations.

However, I perceived from the very first that an appli-

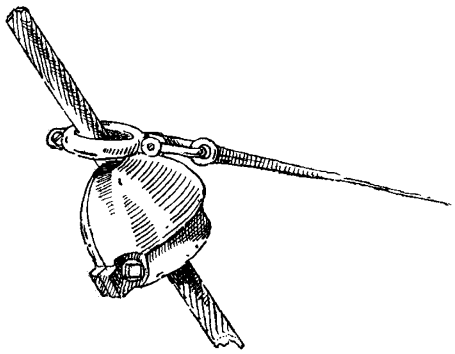

FIG. 4.

ance of this sort would not be able to afford us much information regarding the occurrence of the larger pelagic animals, such, for instance, as cephalopods, decapod crustaceans, and deep-sea fishes. Both the *Challenger* and *Valdevia* expeditions employed, as will be remembered, a big tow-net, with which they made many vertical hauls from great depths to the surface of the sea. By this means they caught a certain amount, though by no means a

particularly large quantity, of fish in proportion to the number of hauls; and they naturally obtained but little information regarding such questions as the depth at which the animals live, and their vertical wanderings by night and day. These questions seemed to me to be of special interest at the present juncture, and accordingly an essential part of the work of our expedition was directed towards their solution. We first constructed some large nets of 3·25 metres diameter, partly of coarser silk and partly of prawn-net, arranged to close on the principle of Nansen's closing net (see Figs. 2 and 3). With these we made several successful hauls at various depths, and obtained sufficient catches of the commonest forms to enable us to determine more approximately the actual depth at which they occur. Nevertheless, we soon discovered that even these large nets yielded merely an incomplete collection of the fauna, since many species occur far too sparsely to be caught with vertical hauls. It was therefore found necessary to employ large horizontal-fishing appliances and to make hauls of considerable length.

Such hauls would, however, take an unduly long time, if they were to be carried out singly at the same station, for hours in succession, at different depths. It was, therefore, particularly desirable to drag a number of appliances at several depths simultaneously. The appliances had in this case to be fastened to one or two wire ropes, as one cannot tow many wires at the same time. The technical difficulty now presented itself that long lengths of wire get twisted, when towed, and consequently destroy the appliances or displace their position in the water. We solved this by an arrangement, shown in the accompanying figure (Fig. 4), by which a shackle to which the appliance is fastened moves freely round the wire. By this means it became possible to have no fewer than ten appliances out simultaneously from two wires, as shown in the figure (Fig. 5). Here we see a series, consisting partly of nets, partly of Dr. C. G. Joh. Petersen's young-fish trawls, in use at the following lengths of wire: 0, 100, 200, 300, 600, 1000, 1500, 2000, 2500, 3000 metres. The total number of these towing stations exceeded thirty.

The material obtained in this way was very large indeed. From the same station hundreds of pelagic deep-sea fishes and litres of large decapods, medusæ, &c., were secured. All the same, the hauls showed that the material was not by any means too large, since right up to the very last haul we continued to capture a few species of pelagic fishes that had not occurred in any of the previous hauls. The largest net, in particular, worked splendidly. We have thus discovered quite a number of species of pelagic deep-sea fish not previously described.

As there were so many stations, and we fished in widely differing waters and at all hours of the day and night, a comparison of these catches with each other will afford much information concerning the geographical distribution of the different species, as well as regarding the depth at which they occur by day and by night, and so on. The catches show that the hauls have much in common, and we may accordingly assume that they are in the main representative of the depth in which the appliances have been towed; and it is further extremely satisfactory to note that the experiences gained from these hauls and from the vertical closing-net are in close accordance.

It is too soon yet, and, moreover, would take too long, to describe in full the results of our experiences. I will confine myself, therefore, to mentioning that everywhere in the Atlantic Ocean, from the Wyville Thomson Ridge to the Sargasso Sea, there appears to be, at depths below 400 metres, a consistently uniform fauna of small, chiefly black pelagic fish, large red crustaceans, numerous medusæ, &c., a fauna which, in any case so far as the fishes are concerned, is probably also shared by other oceans, and which presents the same variety of form that the *Valdivia* expedition, for instance, has found in the Indian Ocean, and the *Challenger* in the Pacific. In the upper layers, at depths less than 400 metres, we have discovered numerous younger stages of fish that are not as yet determined, mostly of transparent, colourless form, such as Leptocephali, to take merely one example.

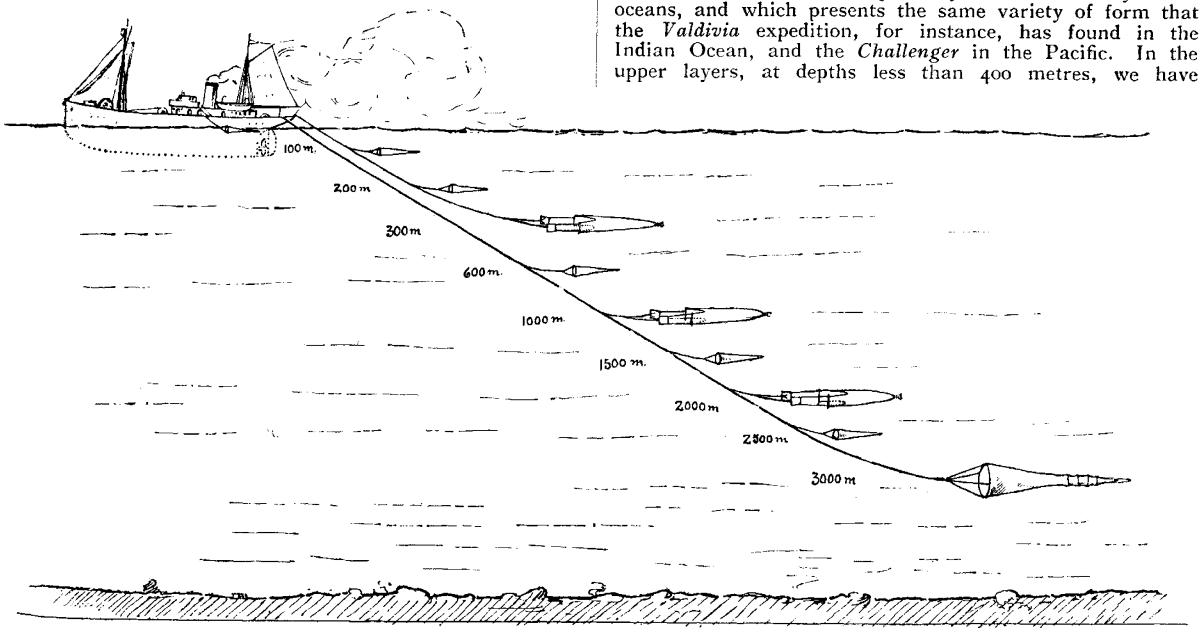

FIG. 5.

TRAWLINGS.

During previous expeditions in the Atlantic Ocean a great number of hauls have been undertaken either with the dredge or with small trawls. There was, therefore, no pressing necessity for the *Michael Sars* to investigate the bottom-fauna of the Atlantic, more particularly as hauls of this nature require a considerable expenditure of time, and could therefore with difficulty be combined with our exacting programme of hydrographical and plankton investigations. It was of interest, on the other hand, to try whether a large-sized model of the ordinary otter-trawl (with 50 feet of head-rope) would yield new results. During my previous researches I had succeeded to my satisfaction, and had secured very good catches, by making use of a trawl of this kind at depths down to 1000 fathoms. It was, in my opinion, especially desirable to employ this appliance along the Continental slope from the Wyville Thomson ridge southwards to the tropical coast of Africa, so as to ascertain the composition of the fauna on this long stretch at depths varying from 500 to 1600 fathoms.

Besides, I considered it of the utmost interest to attempt some hauls far out from the coast-banks on an oceanic deep plain with depths descending to 3000 fathoms. Altogether we have carried out twenty-two hauls at various depths with this large trawl.

It will be seen that our trawl had a greater capacity than any of the appliances previously employed, and that it can therefore, without doubt, be recommended for investigations of the deep-water fish-fauna. This is especially the case where it is requisite to have many individuals for examination. For invertebrate organisms, on the other hand, smaller and more handy appliances may be preferable.

Essentially new types of fishes the trawl cannot be said to have taken. But the material we possess furnishes a good picture, especially of the uniform fish-fauna to be met with along the slopes of the coast-banks of Europe and Africa from the Wyville Thomson ridge down to Cape Bogador, and it also shows clearly the sharp transition from the southern to the northern side of the Wyville Thomson ridge, which the *Triton*, the *Knight Errant*, and my own investigations, amongst others, had previously demonstrated.

The hauls at great depths (about 5000 metres) were no doubt few, perhaps too few; but they accorded with each other and with the hauls made by previous expeditions, more especially those of the *Challenger*, *Travailleur*, and *Talisman*, in indicating that the actual eastern deep-ocean plain of the Atlantic is especially poor in all kinds of higher organisms and particularly in fish. It might, by some naturalists, be regarded as a desert region. A fuller discussion of our observations must, however, be reserved for a more comprehensive publication.

JOHAN HJORT.

THE ASSOCIATION OF TEACHERS IN TECHNICAL INSTITUTIONS.

THE annual meeting of the Association of Teachers in Technical Institutions was held at the Northern Polytechnic, London, on Saturday, November 5. In moving the adoption of the annual report of the council, Mr. J. Wilson (Battersea Polytechnic), the retiring president, stated that any further extensive progress in the general technical and scientific education of this country depends upon the adoption of certain educational reforms, for most of which public opinion is now ripe. These reforms may be briefly summarised as follows:—(1) elementary education to be more practical or constructive; 2) compulsory attendance at day or evening (preferably day) continuation schools, with a limitation of the hours of labour of adolescents; (3) the institution of "technical-secondary" schools; (4) the linking of the elementary school through the continuation and secondary school to the technical school; (5) the increased provision of scholarships, with adequate maintenance grants, so that the qualified day and evening technical student may receive the highest possible technical and scientific training. These suggested reforms are all quite practical, and their adoption would entail but relatively little strain upon the financial resources of this country, while the commercial and educational results would be of incalculable benefit.

Attention was directed to the promise held out in the Prefatory Memorandum to the recent Board of Education regulations for technical schools, that the Board would take action, in the near future, with respect to certain of the more pressing of the educational reforms just referred to. A significant statement in the memorandum, relating to the payment of grants for technical instruction to institutions of university rank, together with the recent formation of a "University Branch" at the Board of Education, emphasises the modern tendency towards bringing the English universities within the purview and influence of the national educational authorities The hope was expressed that this would result in the opening wider of the doors of the university to the community, and a closer connection of the universities with all phases of educational effort in this country.

The recent regulations of the Board of Education respecting the registering of the attendance of day and evening students at technical institutions were criticised adversely, inasmuch as by considerably increasing the time and attention to be devoted by the teacher to the merely mechanical work of registration, they inevitably detract from the efficiency of the teaching as a whole.

In discussing the first volume of the minutes of evidence submitted to the Royal Commission on University Education in London, Mr. Wilson stated that in this evidence there appears vague and unjust criticism of the higher work of the London polytechnics, generally based upon want of knowledge of the work these institutions are now doing.

The president of the association for 1910–11 is Mr. Barker North, of the chemistry and dyeing department, Bradford Technical College.

METEOROLOGICAL RELATIONSHIPS.

PROF. H. HILDEBRAND HILDEBRANDSSON is continuing his important series of papers on the centres of action of the atmosphere, and the fourth communication, recently received, is entitled "Sur la Compensation entre les types des Saisons simultanés en différentes régions de la Terre" (*Kungl. Svenska Vetenskapsakademiens Handlingar*, Band 45, No. 11). In his third paper he suggested that the principal cause of the different types of seasons depended very probably on the condition of the ice in the polar seas, and the evidence he brought forward was such as to show that this view had very much in its favour. In the present communication he makes a closer study of these compensations between the types of simultaneous seasons in both winter and summer seasons, and extends his researches to North America. He further directs attention to some analogous results which he finds exist in the southern hemisphere. Thus he finds both in winter and in summer that there occurs an opposition between the north and south of both Europe and of North America, and also probably between the sub-polar regions and sub-tropical regions of the southern hemisphere. There is also, in general, an opposition between the north of Europe and Siberia.

Special attention is directed to some regions where this opposite nature of seasons is in some years less pronounced, and Prof. Hildebrandsson points out that these districts are intermediate between the main centres of typical action, and are therefore dependent on the intensity of the latter. This communication is accompanied by several plates of curves, and these should be closely studied in connection with the text. There is little doubt that these researches will in time open up a field for the future forecasting of seasons, but it is important to bear in mind that so intimate are the meteorological associations between very widely separated regions on the earth, it behoves the investigator to take a very broad view of the subject, and not confine himself to one small portion of the earth's surface.

Mr. E. T. Quayle, of the Australian Commonwealth Meteorological Bureau, has recently (Bulletin No. 5, March) published the results of his investigations in relation to the possibility of forecasting the approximate rainfall for northern Victoria. At the outset he states that it has long been his conviction that ordinary statistical methods must prove inadequate, and that they do not enable the essential differences between the weather of successive years to be grasped. In his study of the storm systems as they have affected Victoria he has made a classification of them, and on this he bases his method of forecasting. The storms which affect Victoria and bring the rain belong to two main systems, one called "Antarctics," which originate in the southern seas, and the other called "Monsoonals," which are of tropical origin. The first-named he divides into two classes:—(*a*) Antarctics, when their centres are too far south to be identified; and (*b*) Antarctic cyclones, when their centres can be located inland or over Bass Strait. The monsoonal low depressions he divides into three groups:—(*a*) monsoonal troughs; (*b*) monsoonal dips; and (*c*) monsoonal cyclones.

By the use of isobaric charts the number of occurrences of each type of disturbance was taken out for each month for the years 1888 to 1909. As the northern districts of Victoria receive most rain chiefly from monsoonal de-