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FOR 1949

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3. Papers must be accompanied by a synopsis prepared according to the direction given on the inside of the back cover.

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6. The cost of author's corrections to proof above what the Council considers a reasonable amount, must be borne by the author.

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Vol. LXI., No. 1.

Proceedings of the Royal Society of Queensland

Presidential Address

ENERGY AND THE FUTURE OF MANKIND

By H. C. Webster, D.Sc., Ph.D., F.Inst.P.

(*Delivered before the Royal Society of Queensland, 28th March,* 1949.)

Of all the abstract concepts of science, there is none which can compare in importance with the concept of energy. There is little need for me to explain to this Society the significance of the term energy, but I should perhaps remind you of the well-known forms which energy takes, viz., the forms of light, heat, sound, electricity, and the even more familiar mechanical forms of kinetic energy (the energy of motion—exemplified by a moving bullet), and potential energy (the energy of position—exemplified by a wound clock spring). Then, too, energy can assume a chemical form, such as the energy contained in fuel ; and, finally, we have of recent years received startling evidence of the existence of atomic energy.

The various things that happen on the earth, all actions, whether of man, animals or of plants, all involve a conversion of energy from one form to another. The explosion of an atomic bomb, the eruption of a volcano, a lightning flash, all represent well-understood types of energy conversion. At the other end of the scale, the ticking of a watch, the uttering of a word, vision, hearing, even the reception of a sensation and the thinking of a thought, all imply energy conversions.

In all these conversions, there is no new energy created and no energy destroyed. The energy which was in the universe at the beginning is still in existence and no new energy has appeared. New forms appear and old forms disappear, but the gain always balances the loss. This law is undoubtedly the most important law of science. It is really this law which gives significance to the idea of energy ; without it the concept would be meaningless.

This law refers to the total energy in the universe, not the energy actually contained in or on the earth. The earth's energy is not necessarily constant in quantity ; in fact it is almost certainly varying all the time. Energy is being added to the earth by the light and other radiations received from the sun (and to a less extent from other celestial objects), and energy is being lost by invisible radiations and in other ways. The gain and the loss nearly balance out, but usually there is not an exact balance.

The standard of living of the human race, even its survival depends on the energy possessed by the earth. But the possession of energy alone is not sufficient. The energy must also be in a form capable of conversion to other forms, that is the energy must be *available*. Without such available energy nothing can be made to happen, not even the minor actions necessary for living. Unfortunately, energy can easily—too easily, in fact—become converted into a form where it is no longer available. Energy in the form of heat, *i.e.*, the energy associated with temperature, is never completely available. Only that part of the heat of any material object which corresponds to a difference in temperature between it and its surroundings can in practice be converted into other forms of energy. The hot gases in a motor car cylinder have available energy ; when they are cooled to the temperature of the cylinder they have none.

Unfortunately, energy has a tendency to become converted into heat. All energy conversions carried out on the earth, with or without our direction, result in a certain proportion of the energy going into the form of heat. There is, so to speak, a heat tax on all conversions. While at first this heat energy may be still partly in available form, the processes of conduction, etc., soon equalize the temperatures and render the energy unavailable and therefore virtually useless. One might think that there would be a possibility of obtaining energy on account of the temperature difference between the surface of the earth and the cold empty space within the shadow of the earth. Actually, this temperature difference does allow the heat energy of the earth and air one important energy conversion, the conversion into infra-red radiation. This conversion is the ultimate fate of the heat energy. As a result of it there is a continuous emission of radiation into empty space ; this is the main way in which the earth loses energy. We can scarcely contemplate making use of the temperature difference to obtain other forms of energy, since, apart from the difficulties involved, to do so would lower the average air temperature and human life can only be maintained over a certain very limited range of temperature.

We have then on the earth two sorts of energy, useful energy, that is, energy available for the operation of our machines, available for making things happen, and useless energy, that is, unavailable energy. When useful energy becomes converted into useless energy we can speak of it as becoming *degraded* or *consumed*, as it is no longer available.

The most important of the machines is, of course, man himself. I have already mentioned that the slightest action of the body, breathing, the beating of the heart, even the transference of sensation, all represent energy conversions. A high heat-tax is imposed on all these conversions, so that the processes of life inevitably result in the consumption of energy. To maintain life, therefore, an intake of energy is necessary. This intake is in the form of chemical energy associated with the food we eat.

The amount of energy intake depends on the sort of life a man is leading, but a representative value for the average rate is about 150 watts ; this means 3.5 kilowatt-hours each day. (These units are the most familiar of the energy units ; a kilowatt-hour is the unit ordinarily used in selling electrical energy—150 watts is about a fifth of a horse-power.)

As a result of the generation of heat within the human body, particularly within the trunk, the temperature of the interior of the body is, under most climatic conditions, higher than that of its surroundings. This interior temperature is subject to a system of automatic controls. These regulate the way in which the body loses heat, and thus maintain the interior temperature closely constant. For example, if the temperature of the surroundings increases somewhat, certain mechanisms increase the ease with which heat passes from the interior of the skin ; if the surroundings become colder, they decrease it. (Other mechanisms also are involved, but details do not concern us.)

Man is assisted in this adjustment of his temperature by the fact that the average air-temperature at sea-level is not very far removed from the temperature at which the human body functions. This air-temperature depends on the amount of radiation received from the sun. As the average temperature of the earth increases, the rate at which it loses energy to empty space also increases, and since loss and gain must roughly balance, the greater the amount of energy the sun provides, the higher the temperature of the earth.

The actual air-temperature at any place may vary quite considerably. Over a certain range of conditions man's regulating mechanism can cope with the situation, but towards the limits of this range the adjustment involves considerable strain and discomfort. At the lower end of the temperature range the wearing of clothing and the use of houses assist materially in this adjustment. They even permit life under conditions in which otherwise it would be possible only by undertaking continuous strenuous muscular exercise; such exertion, of course, increases the heat evolution within the body.

In his quest for comfort man has resorted to other measures, more important from the point of view of my discussion to-night. He can produce in a limited region such as the room of a house, a modified climate, hotter or colder than the external climate, as may be required. This modification of climate always demands the consumption of energy, *i.e.*, the conversion of energy from a useful form into a form of heat which is useless. The actual steps in this degradation will differ in different cases, but it always occurs. The amount of energy consumed depends not only on the temperature differences maintained, but also on such things as heat insulation, etc. Considerable technical development has been devoted to reducing this wastage of energy. Even now, however, a man may consume more energy keeping warm on a winter evening than he consumes as food during the day.

If man's needs were limited to food and warmth his energy requirements would be relatively easily met. But modern man demands far more. He requires to cook his food to render it more palatable ; in so doing he may expend almost as much energy as the food itself represents. The growing of his food is no longer a matter which occupies merely his own muscular effort. He requires all sorts of implements, many of them requiring additional sources of energy, particularly fuel, for their operation.

To obtain these and other implements man occupies himself in manufacturing, making not only implements, but also houses and the attributes of comfort, and making amusements and luxuries. All manufacturing involves the consumption of energy. Energy is consumed at the mine where the ore is obtained, energy is consumed at the smelters where the metal is extracted, energy is consumed on the railways when the metal is taken to the factory, and energy is consumed at the factory itself and in the subsequent journey to the user. Mostly such energy is the result of the burning of fuel, coming from the chemical energy of wood and coal and oil. But energy must also be provided to the men who work in these occupations, energy to provide them with the necessary food and warmth and the other requirements of modern civilization.

There is a link between the cost in money of a manufactured article and the amount of energy consumed in making it. They do not correspond exactly, for often there are other factors involved, but it is possible to estimate roughly the comparative cost of articles if we know the energy involved in making them. Of course we have to make the machinery used in making the articles, and we must include part of the energy-cost of the machinery when we estimate the energy-cost of its product.

Among the most important products of man's labour are the fuels themselves ; coal and coal products, petroleum and its products, forest products, etc. The relative energy-profit on such operations is a matter of the greatest concern to any community. To find the relative energy profit, we add together the fuel energy expended in mining, transport, refining, etc., and the food, etc., expressed in terms of energy, required by the personnel employed. Then we subtract the result from the energy provided by the fuel. This gives the profit, and we can express it as a percentage in the usual way. If the total cost per ton is, say, 3,000 kw.-hrs., and if the energy we obtained from a ton is, say, 10,000 kw.-hrs., the relative energy profit is 230 per cent. It is not a coincidence that the United States, which has plenty of easily-won fuel, is the richest country in the world. On the other hand, England's post-war financial difficulties are related to the increasing difficulty of winning coal in a country whose best coal-seams have already been exhausted.

The manufacturing activities of a modern industrialized country may consume energy at the rate of more than 1,000 watts per head of population, compared with the 150 watts per head required as food. This does not, of course, represent the whole requirements of the population ; it requires energy for artificial lighting, for transport, for radio and other entertainment. As the use of motor cars becomes more widespread, as the devices for providing entertainment become more elaborate, the demands on energy increase. A petrol consumption of 100 gallons per annum, a quite modest figure in pre-rationing days, represents an average energy consumption at the rate of around 500 watts.

Average energy consumption rates for a typical person are somewhat as follows :—

Food	150 watts
Warmth	200 ,,
Manufacturing	2000 ,,
Transport	200 ,,
Miscellaneous	450 ,,
TOTAL	3000 ,,

TOTAL DAILY CONSUMPTION—72 KW-hrs.

My estimates are based on peace-time requirements. In time of war, energy is consumed at a rate many times greater than in peace, and with the introduction of new weapons the consumption rises hugely. The dropping of a single atomic bomb each day alone corresponds to a consumption at the rate of forty thousand million watts, about 20 watts per head of the world's population.

If the spirit of man throughout the world is to be freed from the chains of poverty, drudgery, and discomfort, if the standards of luxury enjoyed among communities such as ours are to be shared by all mankind, the average consumption of energy, food and fuel must inevitably increase, and increase by a considerable factor. If war, disease and famine decrease their toll, as we hope will be the case, the number of energy consumers will also increase ; again we will require more energy. How then are we to maintain and increase our present supplies of available energy ?

Let us first examine the sources from which we obtain the energy we consume at the present day. The most important group of these sources, and the only absolutely indispensable one, is the food supplies. We eat many things, some animal, some vegetable. Since the animals, however, depend on vegetation as their source of food, we can regard vegetation as the ultimate source of all our food. We must remember. of course, that the energy we obtain from eating the flesh of animals is but a very small fraction of the energy those animals have consumed.

The growth of plants represents, in general, a storage of energy, This energy is obtained from the light which the plant receives from the sun by a photosynthetic process. This most important process occurs chiefly, if not entirely, in the green leaves of the plant. To be precise, it occurs in the *chloroplasts*, organs which contain the pigment *chlorophyll* together with other pigments which may or may not participate in the process. Under the influence of the light absorbed in the chloroplasts, carbon dioxide is synthesized into sugar and energy is thereby stored as chemical energy. This is the principal photosynthetic process, but others also occur with which I shall not deal in detail. The overall efficiency of the process is unfortunately very low. It has been estimated that, of the solar energy falling on a green leaf, only two-thirds of one per cent. is actually stored as chemical energy.

PRODUCTION OF USEFUL ENERGY.

Mechanism	Uses that part of the Sun's Energy which falls on	Efficiency of use
Plants (photosynthesis in chloroplasts containing chlorophyll)	Green leaves and green vegetation generally	0.66%
Hydro-electricity (rain on mountains)	Ocean and other water ...	0.001% (?)
Winds (heating of tropical regions) ...	All earth	perhaps 0.00001%
Photo-voltaic effect	Photo-voltaic cells	0.3%

The efficiency is not the same for all parts of the light spectrum, though this seems to depend to some extent on the species of plant involved. The energy of the infra-red radiation, which makes up about half of the energy in sunlight, is not stored at all by plants.

Plants are of many kinds, not all of which contribute to our food supplies either directly or indirectly. Among the non-food-producing plants, however, are many which can still be regarded as useful ; for constructional timber, for example, or for fuel. The fuels we are using at the present day, chiefly wood, coal and oil, were all derived from vegetation which, in the past, grew with the aid of sunlight. Coal and oil have suffered many chemical changes but have still preserved the chemical energy given to them by the sunlight. Oil may, in fact, have acquired additional energy, derived perhaps from the residuum of the large heat energy which the earth possessed before it became a cold star.

In spite of the low efficiency of the photosynthetic process, it is of vital importance, since it represents virtually the only one which is replenishing those stocks of available energy which we are at present using in such a prodigal fashion. Needless to say, the rate of exploitation far outreaches the rate of restoration ; I doubt if there is any country in the world which is actually increasing its reserves of energy in the form of food and fuel.

These considerations bring home to us the seriousness of the tragedy involved in the loss of arable land owing to wasteful farming transforming it into a desert or dust-bowl. This has been stressed in relation to the growing shortage of food—of which Sir John Boyd-Orr rightly warned the peoples of the world—but this food shortage is but one aspect of the more serious problem. Possibly, by using some of the areas at present devoted to forests for food production, the food position could be corrected, at least for some years, but this would aggravate the general energy shortage. On the other hand, if ample supplies of disposable energy become available, if the general energy problem is solved, there would probably be no need for anxiety regarding the food position, for I have little doubt that organic chemists will be able to discover efficient processes (perhaps some new photosynthetic processes) whereby foodstuffs can be made from carbon dioxide in factories in much the same way as they are now made naturally in plants.

Incidentally, calculations which have been made of the extent of coal and oil reserves in various countries may be misleading, for upon the completion of exploitation of the richer and more accessible deposits the energy costs of mining and transport will rise, perhaps sharply. Without a serious drop in the standard of living, exploitation of the remaining deposits may thus be impracticable. It is well known that for technical and economic reasons, few coal-seams are ever completely removed, and the cost of removing the residues at a later date may well be prohibitive.

Fortunately, we do not depend entirely on fuel for the energy we require for domestic heating, manufacturing and transport. A second process initiated by the solar radiation provides us with a second source, that of hydro-electric energy. The primary effect of the solar radiation in this case is the evaporation of water, principally from the surface of the oceans, but also from moist land, lakes, etc. The air thus moistened may be carried by the winds, which are themselves a product of solar radiation, over mountains and highlands and there, by cooling, the moisture is deposited as rain. The water collecting at the high altitude possesses energy, potential energy, and by suitably directing the water-stream as it flows towards the sea, we can convert some of this potential energy into other useful forms. In modern times, electricity is usually the form of energy produced.

This energy is not produced without cost, *i.e.*, without an initial energy-outlay. Energy must be used in constructing dams, canals, pipes, turbines, dynamos, etc. Most of the hydro-electric schemes which have been installed in different parts of the world, however, have proved highly profitable undertakings. The energy-cost of construction has been covered by the energy produced within a relatively small number of years. Probably there are still many possibilities for highly profitable installations of hydro-electric schemes throughout the world, and many others which, with care, would eventually return a profit in energy, but only after many years.

Unfortunately there are conflicting demands on the available streams of water in many countries, particularly in Australia. We have frequently to choose between the utilization of the water for stimulating an increase in food-production, thereby employing usefully more of the sun's radiation, or obtaining electric power from it directly. Sometimes it is very difficult to determine which of these alternatives will give the greatest overall energy-profit.

I have tried to obtain an estimate, for comparison with the plant-growth method of utilizing solar radiation, of the average overall efficiency of the production of electric power by evaporation from the oceans. I can find no published figures, but on very rough assumptions, I arrive at a figure of one part in 100,000 of the energy falling upon the ocean being potentially convertible into hydro-electric energy. This is probably a considerable over-estimate. Continental Australia with its low rainfall, and small areas of high lands, is rather worse off than most countries in relation to its size, as far as possibilities of hydro-electric generation is concerned.

Other means of utilizing solar energy have also been used to a limited extent. Perhaps the most important of these is the use of wind-power which was developed at one stage in the earth's history to a considerable degree, but recently tending to be abandoned on account of its unreliability. It is extremely difficult, in fact impossible, to estimate the overall efficiency of the wind-power method of using solar energy, but it must be extremely low.

An interesting method for converting solar radiation into available energy which has been suggested is the application of the *photo-voltaic effect.* In the photo-voltaic cell, a comparatively simple electrical device, electrical energy is generated when energy in the form of light falls on the cell. Photo-voltaic cells are in fairly general use as illumination-meters, photographic exposure-meters, and so on. It has been estimated that the overall efficiency of the ordinary selenium photo-voltaic cell is about one-third of one per cent. This method of utilizing energy would thus be only about half as efficient as the utilization by plants. It would have the advantage, however, that a supply of water, salts, etc., would not be needed, so it might be quite convenient for use in desert and semi-desert areas, such as exist in parts of this country. It has been estimated that 4,000 watts of power could be obtained from an acre covered with such cells. Unfortunately, the cost in energy of the manufacture of the cells is so high that it would be quite uneconomic to proceed with large-scale projects on this basis.

Claims have been made by certain Russian investigators that a much more efficient form of photo-voltaic cell has been discovered. If these claims are substantiated, the invention may prove a very valuable one, especially to countries like Australia. Maybe in the future, when ruthless agriculture has denuded our mountains of all but solid rock and converted our plains into deserts, the countryside will be covered with photo-voltaic cells instead of forests, and maintenance engineers will take the place of tillers of the soil.

It should not be thought, of course, that the methods already known for utilizing the sun's energy are necessarily the only or even the best methods available. The total average rate at which energy is received from the sun works out at about two hundred million watts per head of population. Compared with this figure our most extravagant requirements appear trivial. Our difficulties arise only from the extraordinary inefficiency of all our methods of using sunlight. The situation is actually somewhat worse than would appear from what I have said, for only a small fraction of the sunlight actually falls upon green vegetation ; only a part of the potential hydro-electric power can actually be obtained because of cost of installation, and so on.

It is perhaps surprising that so few deliberate searches are being carried out for new methods of converting solar radiation into commercially useful energy. The reason is the absence of any obvious lead, save the photo-voltaic cell scheme I have already mentioned. Other possible schemes, such as the use of the thermo-electric effect, for example, have been shown to be completely unprofitable. In the circumstances, the solution of the problem is more likely to arise out of discoveries in a completely unrelated field of physical or biophysical research than from the results of investigations designed specially to this end.

At the present time, the problem of the world's energy deficiency is being tackled along rather different lines. To understand this work, we must enquire into the actual source of the solar radiation ; we must determine why the sun retains its temperature, in spite of the enormous amount of energy it is continually pouring out, mainly into the unbounded vastness of interstellar space. The rate at which the sun loses energy is nearly four hundred quadrillion watts (4×10^{26} watts), and some process of energy-conversion must necessarily be occurring within the sun for such an emission to continue without decreasing temperature.

It now seems fairly certain that the sun derives its high temperature from the continuous conversion of its *atomic energy* into heat. The existence of atomic energy has been recognized for a comparatively few years. Its nature can be approximately explained in the following way :

Atoms are the building-blocks out of which matter is built, but an atom itself is built up of smaller bits, rather in the way that the solar system is built. Most of these sub-atomic particles are unimportant for our present purpose, but there is in each atom one *nucleus* which is, so to speak, the real body of the atom. This nucleus possesses most of the mass of the atom, and with the nucleus is associated a certain amount of energy. This energy is termed atomic energy. Atomic energy is then really *nuclear* energy. It is conceivable that a nucleus might go out of existence, in some sort of catastrophic process, in which case the atomic energy would be converted into another form, probably into radiation. Naturally, the mass would disappear with the disappearance of the nucleus. On modern views, mass is really a measure of total energy and, if a nucleus or anything else loses energy, it loses mass in proportion.

Such catastrophic disappearance of a nucleus has never been detected. We do know of cases, however, in which part of the nuclear energy becomes converted into other forms, and consequently the mass, the energy indicator, becomes reduced. For example, it can happen when a nucleus splits up into two separate nuclei ; the atomic energies associated with two separate nuclei, added together, being in certain cases less than the atomic energy associated with the single nucleus. This disintegration process can occur spontaneously in *radioactive* elements such as radium ; in fact, the value of radium as a method of treating diseases is closely bound up with its ability to disintegrate and thereby set free some of its atomic energy.

In the atomic bomb also there is a conversion of atomic energy due to the splitting-up of nuclei ; in this case the nuclei of plutonium. This reaction is not spontaneous, like the disintegration of radium, and consequently we can control its initiation.

The process occuring in the sun is of quite a different nature. Although the splitting-up of heavy nuclei, such as those of plutonium and radium, can lead to the conversion of atomic energy into other forms which can be used, the splitting-up of many light nuclei, notably the breaking-up of a helium nucleus into four hydrogen nuclei, actually involves the production of some atomic energy out of other forms of energy. (Atomic scientists will realize, of course, that the manufacture of hydrogen nuclei from a helium nucleus actually implies more than a mere splitting-up, but I do not want to complicate the argument.) If we reverse the process by building up helium from hydrogen, it should be possible to set free some atomic energy, that is, convert it into other forms which we can use. It may perhaps seem paradoxical that while in one case disintegration lowers atomic energy, in the other case it leads to an increase. Nevertheless, by considering the structure of nuclei in detail it is quite possible to arrive at a consistent explanation. However, this is too long a story to enter into now.

This synthesis of helium from hydrogen is, we believe, continually operating in the sun. It is scarcely feasible that this synthesis should occur simply through four hydrogen atoms coming together. Rather it would appear to take place in stages, a carbon nucleus acting as an intermediary in the process. The details are still somewhat speculative. The present theory postulates a chain of six nuclear reactions, which incorporate the hydrogen nuclei one at a time and set the carbon nucleus free again at the end, the net result being the combination of the four hydrogen nuclei into helium. We can equally well regard the process as beginning with nitrogen instead of carbon, but this is a matter of detail.

Adopting this theory of the sun's activity, it is not difficult to provide a reasonable account for the approximate constancy of the sun's temperature and energy output. I say approximate because disturbances of the sun's surface, notably sunspots, eruptions, etc., are of comparatively frequent occurrence, and appear to influence the amount of radiation. It seems likely that the sun's output will change relatively slowly over the next few millions of years. It will probably slowly increase at first but, after the lapse of many millions of years, it will drop and continue to drop until the sun is a cold star like the earth and all life is extinct. It is possible, of course, that at some earlier stage the sun will explode, as some stars have been known to do, and life would then be destroyed in a more sudden and spectacular manner. The sun is, after all, a large-size atomic bomb.

The energy that results from the synthesis of helium is very great, far greater than any ordinary burning of a comparable mass of fuel can produce.

The energy-output of the sun is obtained at a cost of less than a quarter of an ounce of hydrogen per thousand kilowatt-hours. The total consumption is large, amounting to three thousand billion tons (3×10^{15} tons) each year, but this is only about one billionth part of the

ENERGY DERIVED FROM FUELS.

Fuel	Form of Energy Utilized	Energy Obtained (KW-hrs per Kgm.)
Wood	Chemical	say 5
Coal	Chemical	say 10
Oil	Chemical	say 12
Plutonium	Atomic	say 30,000,000
Uranium-235	Atomic	say 25,000,000
HYDROGEN	Atomic	150,000,000

sun's total mass. We do not know precisely what proportion of the sun consists of hydrogen, but there is evidence that hydrogen must constitute an appreciable fraction of the total, so there is no need to fear the hydrogen supply running low for a few million years or so.

Since the earth, like the sun, is composed partly of hydrogen—about one per cent. of the earth's crust consists of this element—one is led to consider whether there is any chance of setting-up, on the earth and under our control, a machine in which hydrogen, in relatively small quantities, could be converted into helium. Such a process could not be made to occur spontaneously, for there are decisive factors which prevent this, but it is conceivable that some process might be devised. We should want one different from the solar process ; it could not be considered because of the enormous temperatures involved. We want then some other process leading to the synthesis of helium from hydrogen.

Such a process, if successful, might provide us with all the energy we need at a comparatively small cost in hydrogen. Taking a figure of ten thousand million kilowatts as the outside estimate of our demands, this corresponds to a consumption of somewhere about a ton of hydrogen per day. As the oceans alone contain about a hundred thousand billion tons (10^{17} tons) of hydrogen, this consumption could scarcely be regarded as excessive. In fact, nearly as much hydrogen is probably being wasted at the present time by the escape of hydrogen gas resulting from the electrolysis of water.

Naturally we could hardly expect 100 per cent. efficiency from our machine, *i.e.*, we could hardly expect all the atomic energy-reduction to appear as useful energy. Further we should have to employ a considerable amount of useful energy in making the machine itself. Even if we had an overall efficiency of only one per cent., however, the consumption of hydrogen could scarcely be regarded as serious.

You may wonder why, when we have a source of energy ready to hand in the plutonium bomb and the nuclear fission pile used in making it, I have stressed the importance of the hydrogen process. The fact is that while the first development of atomic energy machines, using uranium and thorium as the raw materials, may provide an immediate solution to the pressing problems of fuel shortages, it cannot be regarded as anything but a temporary solution. This is due to the fact that the high-grade ores of uranium and thorium will almost certainly be rapidly exhausted ; in fact, the atomic bomb manufacturing programme of the United States will probably exhaust them before the end of the century. Low-grade ores may still be used—they almost certainly will be used for atomic bombs unless a better bomb is invented in the meantime—but their use will not be profitable in terms of energy. Precisely at what stage the process will cease to provide an energy-profit cannot of course be predicted.

If the long-term solution must lie in a hydrogen-helium process, how are we to discover a suitable process ? There is no obvious line of attack. For this reason the Atomic Energy Establishments of Britain, France and the United States, together with University and other research laboratories, are devoting their activities very largely to quite general researches into nuclear physics. Only by the process of slow compilation of information concerning nuclei and their behaviour, only by the elucidation of their fundamental properties and the phenomena connected with them, can we hope to make progress. The solution, when it comes, is more likely to result from some apparently quite irrelevant research than from a straight-forward attack on the problem.

This is the reason why physicists are impressed with the importance of nuclear research ; this is the reason why they are sometimes somewhat impatient of the apathy, even obstruction, with which their proposals are often received. Those who, because of the belief that nuclear research necessarily means military research, or for personal or political advantage, oppose or obstruct nuclear research, are doing a very real disservice to mankind. If all the peoples of the world are to possess and maintain a standard of comfort and luxury such as the more fortunate peoples now enjoy, the energy supply problem must be solved, and must be solved soon.

CONTRIBUTIONS TO THE GEOLOGY OF BRISBANE

No. 1.—Local Applications of the Standard Stratigraphical Nomenclature.*

By W. H. Bryan, M.C., D.Sc., and O. A. Jones, D.Sc.
University of Queensland.

(*Received* 17*th May*, 1949 ; *read before the Royal Society of Queensland*, 31*st October*, 1949 ; *issued separately* 30*th December*, 1950).

In the following proposals an attempt has been made to conform to the Australian Stratigraphical Nomenclature suggested recently by Glaessner and others (1948). In accordance with rule III f of the Code as there set out the new names now introduced are explicitly defined, the geographical features from which the names were taken are stated and the specific type localities cited. Where changes are proposed the reasons are concisely stated.

Rocksberg Greenstones.—A formational name introduced to replace the term " Greenstone Series " of Denmead (1928). The formation consists almost entirely of metamorphosed andesitic and basaltic lavas and tuffs. The name is taken from the village of Rocksberg, near Caboolture, where Mr. R. T. Mathews, who is working on the formation, reports it is typically developed.

The reason for the proposed change in name is the absence of certain knowledge of its age and range in time, which precludes it from any more precise category than that of a formation. It is now ranked as such and named accordingly.

Bunya Phyllites.—A formational name introduced to replace the term " Bunya Series " of Denmead (1928). The formation consists essentially of pelitic rocks such as mica phyllites with some quartz-mica schists ; psammitic rock types are well represented only in the eastern part of the area, and even there they are restricted to the uppermost part of the formation. As here redefined, the formation excludes certain cherts and quartzites (which were included in the uppermost part of Denmead's Bunya Series) and places the top of the formation immediately below the lowest of these, the Kenmore Quartzite, which outcrops near the mine at Gold Creek and can be followed in a direction S. 30° E. to Fig Tree Pocket and thence in a more easterly direction to the Carrington Rocks at Corinda. The formation conformably succeeds the Rocksberg Greenstones, and is conformably overlain by the Neranleigh-Fernvale Group. The name is based on Bunyaville, an outer suburb within the area of Greater Brisbane, where the formation is well developed.

The reason for the proposed change in name is the absence of certain knowledge of its age and range in time.

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*For several years the authors have been collecting material for use in a book to be published under the title of "The Geology of Brisbane." Following a study of the relevant literature and after considerable work in the field they have come to a number of conclusions that differ importantly from those now generally accepted. These conclusions will be set out as such in the book, but it would seem that the arguments on which they are based would be more appropriately stated in the Proceedings of this Society.

NERANLEIGH-FERNVALE GROUP.—A new composite name which incorporates in the one term both the " Neranleigh Series " and the " Fernvale Series " of Denmead (1928) and at the same time changes the category from series to group. As here redefined the Group includes certain cherts and quartzites which were originally included in Denmead's Bunya Series and the lowest of which, the Kenmore Quartzite, is regarded as the base of the group. The name Neranleigh was originally taken in part from the village of Neranwood and in part from the town of Beenleigh, both to the south of Brisbane, while the name Fernvale was derived from a township in the Brisbane Valley to the west of Brisbane. The type locality for the Group as such, now selected by the authors, is the valley of Moggill Creek, within the area of Greater Brisbane.

The reasons for the amalgamation of these two " Series " are : The absence of any structural break within the group and the recurrence of similar lithological types throughout the group. For many years greywackes had been regarded as characteristic of the lower (Neranleigh) part of the group and radiolarian jaspers as equally typical of the upper (Fernvale) part, but the Moggill Creek section shows some of the jaspers occurring at relatively low horizons within the group and some of the greywackes at relatively high levels. The group is highly variable lithologically and includes, in addition to the greywackes and jaspers (which have been over-emphasised in the past), such rocks as phyllites, quartzites, both thin-bedded and massive, impure limestones and calc-epidote rocks.

The Group conformably succeeds the Bunya Phyllites.

Neither the age nor the range of the Group is known sufficiently accurately to enable the use of a more precise term than " group."

BRISBANE METAMORPHICS.—A name introduced to replace the term " Brisbane Schists." Although of uncertain origin the latter designation has been widely used for many years as a comprehensive name covering the immense thickness of metamorphosed marine sediments, tuffs and lavas made up of the Rocksberg Greenstones, the Bunya Phyllites and the Neranleigh-Fernvale Group as defined in the preceding paragraphs. (*See* Bryan and Jones 1944, p. 13.)

The geographical portion of the proposed name is taken from the city of Brisbane within and near which the Metamorphics are typically developed.

The reason for changing the second part of the name from " Schists " to " Metamorphics " is that although schistose rocks of several types are present they are by no means as dominant as the original name would suggest.

The term " Brisbane Metamorphics " is not in strict accordance with the Stratigraphical Code, but the authors feel that some additional and more comprehensive designation is warranted to indicate the unity in general characters which distinguishes the Brisbane Metamorphics from all later stratigraphical units and which overrides those less fundamental differences which have led to the recognition within the Metamorphics of two distinct formations and one group. The term " Brisbane Complex " was considered as an alternative, but was rejected as being at odds with this essential unity and, moreover, as likely to lead to confusion.

Brookfield Volcanics.—A name proposed for a succession of flows, tuffs and agglomerates of varied character but predominantly rhyolitic. The name is taken from the village of Upper Brookfield in the western part of Greater Brisbane. The Volcanics are typically developed near this locality on top of the divide between Moggill and Pullen Vale Creeks.

The age of the Brookfield Volcanics has not been determined but they rest unconformably upon steeply dipping beds of the Neranleigh-Fernvale Group.

Brisbane Tuffs.—This name represents a reversion from the term " Brisbane Tuff " now in common use to Dunstan's (1916) original designation for the accumulation of tuffaceous materials of a rhyolitic nature occurring within, but almost at the base of the Ipswich Coal Measures as developed at many points within the city of Brisbane. The Tuffs have been assigned to the Middle Triassic. (*See* Bryan and Jones 1946, p. 52.)

The use of the plural is advocated as an indication that the tuffaceous material is of several different kinds, including water-laid tuffs, wind-blown tuffs and welded tuffs (Ignimbrites), and that these do not all occur on precisely the same stratigraphical horizon.

Ipswich Coal Measures.—It is recommended that this name be selected from the several synonyms now in common use (*see* Bryan and Jones, 1944, p. 41) for the freshwater shales and sandstones, some of them coal-bearing, that with conglomerates and some tuffs make up a succession of 4,000 feet of strata, the lower limits of which occur on the right bank of the Brisbane River near Mt. Crosby where they rest unconformably on beds of the Neranleigh-Fernvale Group, and the upper limit of which is immediately beneath the Aberdare Conglomerate at Denmark Hill, Ipswich. They have been assigned to the Middle Triassic (*see* Jones and de Jersey 1947d, p. 82 ; Bryan and Jones 1946, p. 54). The place-name is based on Ipswich, and the Measures are typically developed within and to the north, east and south of that city. With rather more precise knowledge of the range of these Measures, it may be possible to promote them to a Series in the sense of the Code.

Bundamba Sandstones.—A formational name proposed in place of the Bundamba Series of Cameron (1907), for coarse fresh-water grits and sandstones, often showing cross-bedding with thin interbedded shales which are commoner towards the base, near which one thin coal-seam occurs. The base is marked by the Aberdare Conglomerate which succeeded the Ipswich Coal Measures after a short erosion interval. The Sandstones have been assigned to the Upper Triassic (*see* Bryan and Jones 1946, p. 54). The place-name is based on an outer suburb of Ipswich, where the Sandstones are typically developed.

The reason for the proposed change is that, in the absence of certain knowledge of their age, these sandstones do not form a " Series " in the sense of the Code.

Brighton Beds.—A name first proposed by Woods (1947), and supported here, for fresh-water micaceous sandy shales often white in colour, but sometimes biscuit brown, together with red and white sandstones and including a curious and easily recognizable horizon of oolitic character. The beds are horizontal and the base and thickness are as yet unknown. They have been assigned to Lower Jurassic (*see* Jones and de Jersey 1947b, p. 11), and are unconformably related to the nearby Ipswich Coal Measures.

The place-name is taken from Brighton, near Sandgate, where the Beds are typically developed.

Redbank Plains Formation.—A name introduced to replace the term " Redbank Plains Series " of Jones (1927). The formation consists of fresh-water clays, mudstones, shales and soft micaceous sandstones together with interbedded basalts on several horizons. The formation

THE GEOLOGY OF BRISBANE

Comparison of Proposed Stratigraphical Terms with those now commonly in use.

European Record	Names now in use		Names now proposed	
Recent ...	— Lone Pine Gravel		Pinkenba Beds Lone Pine Gravel	
Pleistocene ...				
Pliocene ...				
Miocene ...				
Oligocene ...	Petrie Series		Petrie Formation	
Eocene ...	Redbank Plains Series		Redbank Plains Formation	
Cretaceous				
Jurassic ...	Brighton Beds		Brighton Beds	
Triassic ...	Bundamba Series Ipswich Series Brisbane Tuff		Bundamba Sandstones Ipswich Coal Measures Brisbane Tuffs	
Permian ...				
Carboniferous				
Devonian ...				
Silurian ...	Brisbane Schists	Fernvale Series	Neranleigh-Fernvale Group	Brisbane Metamorphics
		Neranleigh Series		
Ordovician ...		Bunya Series	Bunya Phyllites	
Cambrian ...		Greenstone Series	Rocksberg Greenstones	

overlies the Ipswich Coal Measures unconformably and has been assigned to the Eocene (*see* Bryan and Jones 1946, p. 67). The name is taken from and the formation typically developed on the Redbank Plains, near the township of Goodna.

The reason for the proposed change of name is that this succession does not constitute a " Series " in the sense of the Code, the range in time being as yet uncertain.

PETRIE FORMATION.—A name proposed to replace the term Petrie Series of Jones (1927). The formation consists of fresh-water ferruginous quartzite-breccias, fine-grained micaceous white and red sandstones and some oil-bearing shales. The formation rests with a slight unconformity upon the Ipswich Coal Measures and has been assigned to the Oligocene. (*See* Bryan and Jones 1946, p. 67.) The name is taken from the township of Petrie, to the north of Brisbane, where the formation is typically developed.

The reason for the proposed change in name is that the succession does not constitute a " Series " in the sense of the Code, the range in time being as yet undetermined.

THE LONE PINE GRAVEL.—A name first proposed by Bryan (1938) and supported here for semi-consolidated quartzitic conglomerates of fluviatile origin found at relatively high levels on the margins of the lower part of the Brisbane River. The gravel is of late Kainozoic age.

The name is based on a tourist resort on the left bank of the Brisbane River some fifteen miles by water above the city, where the gravel is typically developed.

PINKENBA BEDS.—A name now proposed for semi-consolidated sands, silts and sandy clays of marine and estuarine origin which are well developed under the low-lying flat areas about the mouth of the Brisbane River. The Beds are of late Kainozoic Age.

The name is based on an outer suburb of the City of Brisbane, where the Beds are typically developed.

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MARINE INSECTS*

By I. M. Mackerras, F.R.A.C.P., Queensland Institute of Medical Research, Brisbane.

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Insects are highly successful and widely distributed animals, which have established themselves in many environments and come to dominate many ecological associations, and yet there are comparatively few records of their occurrence in the seas. This review has been stimulated by Wassell's (1948) most interesting discovery of *Pontomyia natans* Edw. in Australian waters and by a few observations we made on a coral cay. It has been necessary to draw largely on information from other parts of the world, because Australian records are for the most part scattered in the literature and rarely accompanied by details of habitat or behaviour.

THE EVOLUTION OF INSECTS.

It is necessary, in the first instance, to remember that insects evolved as terrestrial animals (Tillyard, 1930 ; Tiegs, 1949). They arose, apparently, in the Palaeozoic from primitive terrestrial Myriapods. The Aptera came first, and Collembola have been found in the Devonian, where they lived " in peat bogs along with Acarids, Crustacea and the most primitive types of vascular plants," a terrestrial, if damp, situation. There was a great evolution during the Carboniferous ; winged insects appeared, and the ancestors of many existing Orders became differentiated. Progressive reduction in loss of water through the cuticle was undoubtedly an important factor in this adaptive radiation, but some insects, such as the stoneflies and the dragonflies, were already becoming adapted to an aquatic existence during part of their life-cycle.

From this time, and still more in the Permian, representatives of more and more Orders invaded the fresh waters of the earth, so that the aquatic insect fauna became an abundant and varied one, which showed many remarkable adaptations to life in ponds, streams and lakes. It is from these that most, though not quite all, of the marine insects arose.

The insects that live in fresh waters are many, but they only represent a portion of the Orders and a fraction of the families of all the insects. So, too, the marine insects only represent a fraction—indeed, a small fraction—of the groups which have invaded fresh water.

ADAPTATIONS TO AQUATIC LIFE.

There are two quite different basic adaptations to aquatic life. The first is shown by those insects which are insulated against the water, frequently by means of a close pile of hairs or scales, the result being that they are not actually in contact with the water. Water-beetles and such bugs as the water-skaters are examples of this type. They may run upon the water, they may even dive beneath the surface, covered with a film of air and carrying their bubble of air for respiration, but they are not wetted. They do, however, live in a saturated atmosphere, and the film of air may play an important part in respiration beneath the surface.

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* Presidential address to the Entomological Society of Queensland, 14th March, 1949.

The second group is truly aquatic. Their bodies are wetted, and they cannot survive out of the water in the aquatic stage of their life-history. They show many special adaptations, of which the most important are :—

1. They no longer need protection from loss of water through the body's surface ; but they do need means to regulate ionic exchange between their body-fluids and the external environment.
2. They require special means to cope with respiratory exchange, either by breathing-tubes which pierce the surface (or sometimes the tissues of aquatic plants), or by blood or tracheal gills, or by increased cuticular permeability to dissolved gases.
3. As water exchange between the insect and its environment is unrestricted, there is no need for any mechanism for storing insoluble excretory products.
4. Wings are obviously useless impediments during the aquatic stages of an insect's life.

Marine insects show the same basic adaptations but they meet special difficulties.

1. The atmosphere surrounding the hydrophobe insects is not quite saturated, and therefore these insects may need more efficient means to control evaporation from the body-surface than their fresh-water relatives.
2. Whether on the surface or beneath it, marine insects face conditions of turbulence which are not usually found in the fresh waters except on the margins of large lakes. Even in swiftly flowing streams, the inhabitants only have to align themselves with the direction of flow, and do not need to cope with changes in direction due to tides, currents, winds, and so on. Buxton (1926) drew attention to this factor, and regarded it as an important though not a vital one in limiting invasion of the sea.
3. In addition to movement, bottom-dwelling insects must be able to withstand changes in hydrostatic pressure due to the rise and fall of the tide.
4. The turbulence-factor determines that insects living below the surface cannot depend on respiratory tubes for their gaseous exchange. Thus, it is well known that mosquito larvae cannot survive in waters where there is splash and wave motion, and it is significant that the larvae of marine Chironomidae have cutaneous respiration and their pupae lack breathing trumpets.
5. Of even greater importance is the need to regulate the exchange of water and ions, and to cope with a reversed osmotic gradient. Morphological evidence of this factor is seen in the reduction of anal papillae in mosquitoes and Chironomidae which live in saline waters.
6. The food factor may also be important. There are so few higher plants in the sea that invasion by phytophagous insects would be extremely difficult. Those which live on Algae, diatoms, etc., in fresh water find less violent change required, and so also do those which live on animal food.

7. A further hazard is probably found in the predatory life. The numbers and variety of predators one sees in ponds and streams are impressive, but those one encounters on rocky foreshores and coral reefs are even more impressive, and they differ, too, in their methods of finding and seizing their prey.

Collectively these are formidable barriers. That they are real is indicated by the fact that almost the only insects to become established in the sea are hydrophobes, which skate on the surface, or shelter in rocks or weeds when submerged, and the larvae of certain Diptera, which have cuticular respiration and efficient means of hiding from their enemies. It may be noted, too, that marine insects are nearly always small (Miall, 1903).

Invasion of the sea probably occurred by two routes : gradually from streams through their estuaries, and by more abrupt changes from pools and swamps to the littoral zone and the reefs. The open ocean appears to have been reached only once by each path. These lines are indicated in Table 1, as well as the rapid decrease in the variety of Orders as one proceeds seaward.

TABLE 1.

ORDERS OF INSECTS IN WHICH AQUATIC SPECIES ARE KNOWN.

Order	Fresh	Estuarine	Littoral	Pelagic
Collembola (H)	x		x	
Ephemeroptera (A)	x			
Odonata (A)	x		(x)	
Perlaria (A)	x			
Hemiptera (H, A)	x	x	x	x
Coleoptera (H, A)	x	x	x	
Hymenoptera (A)	x(¹)		x	
Neuroptera (A)	x			
Diptera (A)	x	x	x	x
Trichoptera (A)	x	x	x	
Lepidoptera (A)	x(²)			
Orthoptera (? H)	x(²)			

H = Hydrophobe adults (sometimes all stages when there is no metamorphosis).
A = Aquatic early stages.
(¹) Parasitic on aquatic insects.
(²) A few genera only. Siphonaptera also occur on marine mammals.

ESTUARINE FAUNA.

The change from fresh water to salt in river estuaries is fairly gradual, so one would expect to find an equally gradual decrease in the fresh water insect fauna as one approaches the sea, and an associated appearance of forms showing progressive adaptation to life in salt water. Such an area should be one of evolutionary change and speciation. Actually, this may not be true, and Buxton quotes evidence that in saline lakes of Europe there is a critical salt concentration which bars colonisation. In waters with a saline content of less than 2.5% species of Odonata, Hemiptera, Neuroptera, Diptera and Trichoptera were found, but only Diptera in those with a salt content greater than 2.5%.

It is difficult to compare these findings with what happens in estuaries because few accounts of estuarine insect faunas have been available to me. Lindberg (1937) gives detailed records of the Hemiptera and Coleoptera of a Finnish bay opening into the Baltic. The salt content of the water was very low (from 0.1% to 2% at different stations), and both Orders were well represented, the Hemiptera by the families Hebridae (1 species), Gerridae (5), Mesoveliidae (1), Veliidae (1), Corixidae (7), Notonectidae (2) and Nepidae (2), and the Coleoptera by Haliplidae (6), Dytiscidae (31), Gyrinidae (5), Hydrophilidae (17), Dryopidae (1) and Chrysomelidae (1). Only 10 species of beetles and 2 of bugs were taken in the most saline (seaward) station. The Plymouth workers (————, 1931) record a caddis fly (*Leptocerus*) at the top of the tidal region in the Tamar R. We have seen Gerrids in the tidal part of the Mary R., and wondered whether they indicated the path taken by the ancestors of *Halobates* on their way to the sea. Chironomid larvae, apparently of two different subfamilies, have been dredged from muddy bottoms at considerable depth (e.g., *Orthocladius oceanicus* Pack. from 30 fathoms in Salem Harbour, U.S.A.).

All this is very meagre. A large and interesting field clearly awaits the naturalist, who will work in the lower reaches of our Queensland rivers and make salinity records in parallel with his insect collections.

LITTORAL FAUNA.

The insect fauna of the shore-line is more varied and better known. The types of situation also vary greatly, and we may consider five very different environments separately.

Mangrove swamp.

It is difficult to know whether to class this environment as littoral or estuarine. I have chosen the former because the Diptera at least have extended to it from the pools and swamps of the land rather than from the streams which flow past its edges. This is well shown by the mosquitoes, nearly all of which can breed—and sometimes do so freely—in water of all gradations from perfectly fresh to brackish or even concentrated sea water, for example *Anopheles punctulatus farauti* Lav. in water from 0 to 1.4% and *A. amictus hilli* Edw. from 0 to 4.2% saline content (Lee and Woodhill, 1944).

The best known insects of the mangrove swamp are Nematocerous Diptera. Mostly they breed in the temporary pools of the inner mangrove zone, left by the high tide and more or less diluted by rain or seepage. Among the Australian mosquitoes, there are, in addition to the Anophelines mentioned, *Aedes vigilax* Sk., *A. alternans* Westw., *A. longirostris* Leic., *Culex sitiens* Wied., *C. vishnui* Theo. and *C. fraudatrix* Theo. (Lee, 1944). It is interesting to observe how completely these forms are restricted to situations which are cut off from direct contact with regular tidal waters. Other occupants of the same environment are Chironomidae (Chironominae) and Ceratopogonidae. Adult *Culicoides* are extremely abundant, and have been found breeding in mangrove swamps in other parts of the world, but the only larvae so far found in this country live in fresh water (Marks, 1947).* The Dolichopodid, *Thinophilus wasselli* Hardy, is plentiful on uncovered tidal mud (Hardy, 1935).

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* Since this was written, Lee (*Aust. J. Sci.*, **12** : 74, 1949) has found the early stages of a pest species in the *Salicornia* zone above ths mangroves in New South Wales.

Open salt marsh.

The insect fauna of the salt marshes in low-lying country behind the sea-front illustrates the effects of salinity referred to by Buxton, most of the species being restricted to brackish waters. It is, however, richer than the estuarine fauna, doubtless due to freedom from tidal action and better shelter from predators. In Hawaii, Williams (1936, and later papers of the series) recorded water-beetles (*Enochrus*), a small, active Corixid bug, and occasionally a dragon-fly (*Anax*) from such brackish waters. Lispine flies, Acalyptrates (chiefly Ephydridae) and Dolichopodidae frequent the margins of the pools.

In Australia, several of the mosquitoes mentioned above breed also in salt marshes. In addition, *Aedes camptorhynchus* Thoms. is a salt-marsh species in southern Australia, where it replaces *A. vigilax*, and Lee has recorded *Culex annulirostris* Sk., usually a typical fresh-water species, as breeding in brackish water.

Sandy beach.

The beach fauna of Australia is interesting, and again is largely dipterous, although Cicindelids (*C. ypsilon* Dej.) are common, and various other beetles occur in cast-up masses of seaweeds or sometimes under rocks. The Cicindelids typify the adult insects of the beaches, for they are pale-coloured and fast-moving, difficult to see and exceedingly difficult to catch. The Diptera-Brachycera have similar habits. At least two robber-flies (*Clinopogon maritima* Hardy and *Stichopogon minor* Hardy), two Apiocerids (*Apiocera maritima* Hardy and *A. pallida* Norris), one Therevid (*Anabarrhynchus maritima* Hardy), one Empidid (unidentified) and a *Tabanus* (*T. vetustus* Walk.) frequent our beaches and, in spite of their capacity for strong flight, seem to have a very restricted habitat. Another pale Tabanid of the north (*T. leucopterus* Wulp), however, ranges widely out to sea and has been taken on ships many miles from the land. The Tabanidae, Therevidae and Apioceridae may be classed as truly littoral, for Miss English (1947) has recently discovered their larvae and pupae in the sand between tide-marks, and has given a full description of the early stages of *Apiocera maritima*.* All these larvae are predatory, but they obviously cannot live exclusively on each other (though they will do so if given the opportunity), and one imagines that their major sources of food must be the Annelids and small Molluscs which are common beneath the surface in the same situation.

An interesting beach-fly described from Hawaii by Williams (1938) is the greyish Dolichopodid, *Asyndetus carcinophilus* Par., which mounts guard at the entrance to the burrows of the sand-crab, *Oxypode;* its larvae live in the sand and are predacious.

Nearer the sea, in fact running at the very edge of the wash, are the smaller but equally agile flies of the Muscid sub-family Lispinae. They are not restricted to the open beach, but have a predeliction also for seaweed masses and the margins of pools, both salt and fresh. Acalyptrate Diptera are also associated with seaweed, living mainly in the decaying material at or above high tide mark. These, with *Sarcophaga* and Carabid and Staphylinid beetles, constitute the " jetsam fauna." The Plymouth workers list seven species, and doubtless as many occur in Australia ; at least Phycodromiidae, Ephydridae and

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* Also (*Proc. Linn. Soc. N.S. Wales*, **74** : 153, 1949) of *Tabanus orarius* Eng.

Sciomyzidae are known here. Finally, one must mention Womersley's (1937a) discovery of the males of *Pontomyia cottoni* Wom. (Chironomidae) in small depressions at the edge of the water on a beach in South Australia. He has also taken them with a light around jetty piles, and thinks that they probably skim on the surface of the water (personal communication). Those on the beaches may have been washed up with the waves. The same species has been taken in Gunnamatta Bay, New South Wales (Lee, 1946). We shall have more to say about this remarkable genus later.

Rocky coast.

This is the richest in species and the best collected of the littoral environments ; it may be taken to include the rocky shores and reefs of sheltered waters, as well as those exposed to the open ocean. Dakin *et al.* (1948) have made a detailed study of the zonation of the latter in New South Wales, and their findings may be tabulated as a basis for marking the distribution of the insects, although most of the records to be considered will not be Australian, and the indications can only be rough approximations (Table 2).

Collembola live both on the surface of supra-littoral pools and in crannies among the rocks between tide marks. When the tide rises, they bury themselves in the sand ; they appear to be completely unwettable. Womersley (1936b) described *Isotoma pritchardi* Wom. from the edge of a reef in South Australia.

TABLE 2.

ECOLOGICAL ZONES OF ROCKY COASTS.

Tide	Belt	Zone	Insects*
High-tide ...	Supra-littoral	V. Littorinid	Thysanura (*Allomachilus*) Collembola Coleoptera (various) Chironomidae, Culicidae
	Littoral	IV. Barnacle III. Galeolaria	Collembola Hemiptera (*Aëpophilus*) Carabidae, Staphylinidae Parasitic Hymenoptera Trichoptera (*Philanisus*) Tipulidae, Chironomidae, Dolichopodidae Spiders (*Desis*) and mites (Pontarachnidae)
Zero low tide ...	Littoral-sub-littoral fringe	II. Pyura I. Kelp	Chironomidae *Halobates*

* Arranged systematically, not in sequence of occurrence.

There are few Hemiptera. *Aëpophilus*, a small bug with a family to itself near the Gerridae, is found in Europe in company with Carabid beetles under stones and in fissures in rock not far from low water (Miall, 1903). Species of *Halobates* occur in the lower zones as well as at sea, *H. whiteleggei* Sk. being common in Sydney Harbour (Skuse, 1891).

Coleoptera are relatively numerous, to judge by the Plymouth Report. Of 116 species listed from coastal Devon, 69 were classed as "coastal," 40 as "sub-maritime," and 7 as "maritime," the last two groups including representatives of seven Sub-orders (10 species of Geodephaga, 4 Palpicornia, 23 Brachelytra, 4 Clavicornia, 1 Lamellicornia, 3 Rhynchophora, and 2 Heteromera). The notes under the species suggest that " sub-maritime " corresponds with zones IV and V, and " maritime " with zones I-III of the Table. Mostly the beetles occurred under stones and seaweed or among barnacles, and only Carabids and Staphylinids appear to extend far into the lower zones. Miall (p. 375) has an interesting note on *Aëpus*, one of the Carabidae : " They run about on stones, seaweed, sponges, etc., at low water . . . they cannot avoid the rising tide. As soon as it reaches them, they creep under stones and remain motionless. The body is flattened, and covered in every part with hairs which entangle air (Audouin). There is a large pair of air-sacs in the abdomen . . . which are no doubt useful during prolonged submersion." Tillyard (1926) notes three maritime Staphylinids (*Staphylinus huttoni* Br., *Cafius littoreus* Br. and *C. maritimus* Br.) as occurring in New Zealand. Though numerous in species and showing some special adaptations, the beetles can hardly be regarded as more than tentative intruders from the land.

Even Hymenoptera occur, Miall noting a small Proctotrupid as having been found under stones in company with marine Crustacea on the coast of France. Its host was not known.

There are also a few Trichoptera, the best known being *Philanisus plebejus* Walk. from Australia and New Zealand. " Its larva feeds on coralline seaweed in rock-pools between tide-marks, and appears to be generally distributed round the coasts of both countries. The sub-cylindrical case is cunningly contrived from small pieces of the food-plant and other objects, so that the larva is most difficult to detect. The imago frequents rocky coasts and is very active." (Tillyard, p. 394.)

Five families of Diptera are represented in addition to the jetsam fauna mentioned above. The Culicidae are restricted to the supra-littoral zone, where they breed in rock-pools containing various concentrations of salt water. In New South Wales, *Aedes alboannulatus* Macq. only occurs when the salt content is low (0.2-0.7%) and *Anopheles annulipes* Walk. is occasionally taken in water containing up to 1.6% salt, but *Aedes concolor* Tayl. is specially adapted to these conditions, and its larvae have been found in water with a saline content from 0.1 to 7.4% (Woodhill, 1936). The adults are also restricted to this zone, the females biting freely at dusk while the males hover overhead in a pre-nuptial dance. A remarkable aberrant Culicine, *Opifex fuscus* Hutton, occupies a similar niche in New Zealand (Miller, 1922) and a Ceratopogonid (*Dasyhelia*) in Hawaii (Williams, 1944).

The Tipulidae occur lower in the series, their larvae being found " among algae on sea-rocks, submerged by the tide " (Alexander, 1931). Almost all belong to four subgenera of the great genus *Limonia*, and their adaptations seem to parallel to some extent those of the Chironomidae (Tokunaga, 1933). Adult Dolichopodidae live in the same zone, haunting the surf and breakers in search of their prey, and even flying over reefs at low tide 100 yards from the shore (Miall, Plymouth Report).

The Chironomidae are the most interesting group in this environment, and show the most complete series of progressive adaptations to a marine existence. Stuart (1942) has described the supra-littoral species of Scotland. The Chironominae live in, and the Tanypodinae on, the mud in brackish pools apparently similar to those described above for the Culicines in this country. They possess haemoglobin and reduced tracheal trunks. The Orthocladiinae occupy pools of varying salinity in the same zone, but extend also into the upper littoral. They lack haemoglobin, have large tracheal trunks, feed on algae, and some species are adapted for quick emergence and oviposition ; one secretes a film of air in the pupal case like Simuliidae. Edwards (1926) follows this group further into the inter-tidal belt, where the larvae live among seaweed and the adults congregate on the wet rocks. In *Camptocladius thalassophilus* Goet., the females do not rise into the pre-nuptial swarm, but wait on the rocks for the males to descend to them. Skuse (1889) has described *C. crassipennis* Sk., apparently from similar situations, in Sydney Harbour.

In the Clunioninae, the larvae occur in the intertidal zone, sometimes deep in pure salt water at the outer fringe, sometimes near the mouths of streams, where there is some admixture with fresh water ; they live in, and mostly feed on, various species of Algae. Emergence of the adults takes place when the tide is out. They mature quickly, and are usually active after dark, scampering half-running, half-flying, over the wet rocks exposed at low tide, sometimes rising in the air over the sweep of a wave (Tokunaga, 1935), sometimes clinging submerged to the rock. They mate on the rocks, and appear to be unwettable.

These species show progressive reduction of adult structures. *Telmatogeton* and *Thalassomyia* have well-developed wings in both sexes, but the males have lost the antennal plumosity, possibly associated with loss of aerial mating. In *Halirytus* and *Eretmoptera*, there is more or less reduction of the wings. In *Clunio*, the wings of the male are short and rounded but functional, while the females have lost wings and halteres, and are carried round attached to the males like miniature Thynnid wasps. Recent revisions of these genera have been published by Wirth (1947a, *Thalassomyia ;* 1947b, *Telmatogeton*) and Stone and Wirth (1947, *Clunio*). Womersley (1936a) has described *Telmatogeton australicus* Wom. from South Australia and given an account of its biology, while Dakin *et al.* record *Clunio pacificus* Edw. from the littoral-sublittoral fringe on the New South Wales coast.

The final step in adaptation to marine life is reached in the genus *Pontomyia*, which properly belongs to the next section. Its larvae and pupae live in delicate mud tubes among the fronds of *Halophila ;* the females lack antennae, mouth-parts, wings, halteres, and all but the stumps of the mid and hind legs ; they probably remain in the tubes where they emerged ; while the males have reduced, distorted wings, and swim actively in the plankton beneath the surface.

It is not to be inferred that the steps described consecutively here represent a single line of evolution. There were three, possibly more, lines, represented by the three subfamilies. The Orthocladiinae probably came down *via* the supra-littoral pools ; the Clunioninae may have entered the turbulence of the sea from the turbulence of rapids and waterfalls, though Wirth suggests that the fresh-water species of *Telmatogeton* are derived from marine forms ; while *Pontomyia* represents an entirely different line of evolution, being derived, according to Edwards, from the Chironomine genus *Tanytarsus* with which it is associated in the *Halophila*.

* * *

A brief note on marine Arachnida in Australia may be given to complete the account of this region. Dakin *et al.* record the spider, *Desis crosslandi* Poc., as building its webs in the *Galeolaria* zone, and note its occurrence from Queensland to Victoria. We have seen what is probably the same species on the outer part of coral reefs, nesting in crevices inside the *Lithothamnion* platform at Hayman Id., and Heron Id., Queensland. Womersley (1937b), records two Hydrachnoid mites (*Pontarachna halei* Wom. and *Litarachna denhami* Loh.) from the littoral zone in South and Western Australia respectively, and has also found Halacharidae among seaweed (personal communication).

Coral reef.

The fauna of this region is an impoverished outlier of the littoral fauna described above, its interest lying in its frequently wide detachment from the land and the purity of the sea-water as indicated by the presence of living coral. I have references to only three groups of insects and a spider.

Collembola (*Axelsonia littoralis* Monz. and *Pseudachorutes* sp.*) occur in the outer parts of the reef inside the rampart in similar situations to *Desis*. They were not uncommon at Heron Id. The marine bug, *Halobates*, lived in the same zone, and seemed more inclined to hide in the coral than to skate on the water. In the Chironomidae, Edwards described four species from Samoa, *Clunio pacificus* Edw., *Tanytarsus halophilae* Edw., *T. maritimus* Edw., and *Pontomyia natans* Edw., and additional Clunioninae have been recorded from other Pacific islands. The last three of Edwards' species are particularly interesting, as they represent the only truly marine Chironomine genera known, and they were associated with *Halophila*, which is one of the few higher plants to invade the sea (Buxton).

PELAGIC FAUNA.

We have followed an ever decreasing insect fauna from the shore to the verge of the littoral belt and to the coral reef. Now we come to the last and smallest group. Only two kinds of insects can be described as pelagic, the Halobatinae and the Chironomine genus *Pontomyia*.

Halobates and related genera skate on the surface of the oceans, often far from land, feeding on animal remains, and laying their eggs on floating detritus. They are unwettable, and live on, not in, the water.

Pontomyia was discovered by Buxton at Samoa. The early stages and the female belong to the reef fauna, but the males are as truly pelagic as the zooplankton among which they live. Buxton collected them with a tow-net, at night, at half to low tide by sweeping the water over the patches of *Halophila*. Wassell (1948) recently collected swarms of males in a night plankton haul in 8 feet of water half a mile from the shore in Princess Charlotte Bay, North Queensland. They were greatly attracted by the strong light which was used to concentrate the plankton, and swam about rapidly beneath the surface, agitating the water as the light was moved. Many clustered on the side of the vessel at the water-line where the light shone strongest. One could hardly imagine more remarkable behaviour in an insect.

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* Determined by Mr. H. Womersley of the South Australian Museum, Adelaide.

CONCLUSION.

This review is admittedly incomplete ; references have been difficult to trace, and some of the literature has not been available in Queensland. Nevertheless, enough has been said to show that the sea is not as devoid of insects as might have been imagined. Naturally, most of the species are littoral in distribution, and the rocky coasts and reefs have proved particularly favourable for colonization. Among their inhabitants, there are some which can enter the sea simply because they are unwettable and the salt water cannot reach their bodies, but others are truly marine. Only about ten families of half a dozen Orders have survived in the full 3.2% salinity of the open ocean, and of these the Chironomidae have shown the greatest variety and perfection of adaptation and the strongest tendency to populate the deeper waters. A wide field of investigation is open to the Australian worker, for our marine insects are still but little known, our coasts and reefs promise to be prolific collecting grounds, and there is no reason why the fascinating study of shore ecology should remain the exclusive province of the marine biologist.

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A NEW ERGOT FROM QUEENSLAND

By R. F. N. Langdon, M.Agr.Sc., Department of Botany,
University of Queensland.

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In 1941 an ergot or *Hyparrhenia filipendula* (Hochst.) Stapf was found a few miles north of Ipswich, Queensland, but attempts to determine the species of *Claviceps* responsible were not successful (Langdon 1942A). In May, 1948, sclerotia were collected from this host at Conandale, South Queensland. Subsequent germination showed that the ergot was a species previously unknown. It was first brought to notice by the development of the saprophyte *Cerebella* on infected spikelets. The amount of honey-dew produced is limited, and after mid-morning it usually dries up, at least on the exterior of infected spikelets, leaving a white encrustation about the margins of the glumes. The sclerotia remain hidden within the glumes and can be detected only by the darker and plumper condition of the spikelets. The name of this new species of *Claviceps* is derived from the unobtrusive symptom-picture shown by infected plants.

Claviceps inconspicua Langdon ; species nova, affinis *C. annulatae* Langdon, sed stromatis colore et indumento differt.

Sclerotia fuliginea, subcylindrica vel fusoidea, in spiculis inclusa, 2-5 mm. longa. Stromata in quoque sclerotio 1 vel plures. Stipites 1.5-9 mm. longi, colore Anthracene Purple (Ridgway) vocato. Capitula globosa, papillosa, in superficie hyphis raris brevibus, in basi annulo hypharum brevissimarum albarum praedita, colore Raisin Black (Ridgway) vocato, 0.3-0.6 mm. diam. Perithecia 155-180 × 105-125 μ. subglobosa. Asci cylindrici, 140-175 × 4 μ. Ascospori lineares, hyalini, Conidia hyalina, guttulata vel granulosa, lateribus recta vel leniter curva, finibus ambobus rotundata, 15-20 × 5-10 μ.

In ovariis *Hyparrheniae filipendulae* (Hochst.) Stapf, Queensland. Prope Conandale, 30th May, 1948, Langdon (425 TYPE) ; prope Ipswich, 28th May, 1941, Langdon (163) ; Grovely, Brisbane, 12th April, 1949 (426).

The sclerotia were kept dry during the winter and subjected to cold treatment (2-4° C. for 28 days). In September they were placed on moist sand in petri dishes. Development of the ascal stage began in mid-November. Germination of the sclerotium begins with the protrusion of a small white papilla which quickly grows out into a globose tuft of white hyphae. The developing stroma is veiled with white hyphae as it pushes up, and at maturity loose hyphal elements persist on the surface of the capitulum. A ring of very short white hyphae is present at the base of the capitulum where it joins the stipe. The tuft of hyphae at the base of the stipe is persistent.

OTHER RECORDS OF ERGOT ON *HYPARRHENIA*.

Goncalves (1937) reported the occurrence of ergot on *Hyparrhenia rufa* in Brazil, and noted an association of *Cerebella* with the sphacelial stage of the disease. There are records of *Cerebella* and *Fusarium* as saprophytes in the honey-dew of ergot of *Hyparrhenia ruprechtii* in Southern Rhodesia (Hopkins, 1947). McDonald (1927) reported the occurrence of *Cerebella* on *Hyparrhenia collina* in Kenya. In Sierra Leone, Deighton (1947) has found *Cerebella* on *Hyparrhenia gracilescens*, *H. rufa* and *H. subplumosa*, but he stated that he did not find it associated with ergot honey-dew. From the work of Langdon (1942B) there seems little doubt that a record of *Cerebella* on a grass is a safe indication of a prior infection of the host with ergot.

DISCUSSION.

In Queensland a number of native grasses are hosts for indigenous species of *Claviceps* (Langdon 1942A). A wide search in south-eastern Queensland since 1946 has revealed only two new hosts for ergot, and both of these were infected by *Claviceps pusilla*. *Hyparrhenia filipendula* is the only host known for *Claviceps inconspicua*. There are at present no other suspected hosts of this ergot, *i.e.*, plants which have been found infected with ergot, the perfect stage of which has not been observed. A consideration of the origin of *Claviceps inconspicua*, whether the fungus is indigenous to Australia or has been introduced, must take into account the origin of its host. *Hyparrhenia filipendula* is a plant about which there has been some doubt as to its natural distribution. Stapf (1934) for the genus *Hyparrhenia* writes : " Species over 60, almost confined to tropical Africa (including the islands) and subtropical South Africa, three of them extending to tropical America, one to Asia and Australia, one to Mediterranean countries and temperate Africa." For *Hyparrhenia filipendula*, Stapf gives the general extra-African distribution as Ceylon, the Philippines, and Australia, but adds that " *Hyparrhenia filipendula* is often found on abandoned plantations, and its occurrence in India, Malaya and Australia may possibly be due to casual introduction."

In Australia, *Hyparrhenia filipendula* is found as a constituent of the herbage in open forest areas, and it occurs also in induced grassland communities following changes effected by man in the natural plant cover. Blake (1942) found *Hyparrhenia filipendula* associated with a number of native grasses in an Open Eucalyptus Forest community at Running Creek in south-eastern Queensland. The herbaceous cover was dominated by kangaroo grass, *Themeda australis*, a species which is amongst the earliest to disappear under grazing conditions. This occurrence of *Hyparrhenia filipendula* in a mixture of native grasses in what must be regarded as an area carrying almost unaltered natural vegetation is worthy of note. That *Hyparrhenia filipendula* occurs in induced grassland communities is not evidence that it is an introduced grass as might be inferred from Stapf's remarks on the occurrence of the species in abandoned plantations. Native grasses frequently are dominant in disturbed ground, for example, *Capillipedium spicigerum* and *Bothriochloa decipiens*. *Imperata cylindrica* var. *major*, a species indigenous to Australia and south-east Asia, often occupies cultivated land which has been abandoned.

Through the courtesy of Mr. S. T. Blake of the Queensland Herbarium, records of the locality and date of collection of specimens of *Hyparrhenia filipendula* in various Australian herbaria have been obtained. The earliest collection was by Leichhardt in 1843, the locality being given as " Eastern Australia." Other early collections are from the islands of Moreton Bay by Mueller in 1855, from the country west of Rockhampton by Bowman in 1867, from the Clarence River (N.S.W.) by Beckler between 1870 and 1880, and from the Apsley River in the

Kimberley district of Western Australia by Crawford in 1887. The distribution of *Hyparrhenia filipendula* in Australia, as indicated by specimens in various herbaria, is from the Clarence River in northern New South Wales to North Queensland, and in the north of Western Australia. Mount Fraser, near Mossman, is the northernmost area from which the species has been collected in Queensland, and the grass has been recorded from a number of coastal and sub-coastal areas at various places between its known southern and northern limits. Crawford's collection from the Apsley River is the only record of the grass in Western Australia. The comparatively late collection of *Hyparrhenia filipendula* in Australia might suggest that the grass has been introduced after colonization of Australia by white men, though its occurrence in places remote from centres of early settlement controverts this idea. If introduced from Africa early in the nineteenth century, the grass might be expected to occur in the south-west of the continent or near Sydney, but it does not. That the climatic conditions in the latitude of Sydney are such that *Hyparrhenia* cannot develop to maturity there is not a tenable hypothesis. There is in the Queensland Herbarium a fertile specimen of *Hyparrhenia* (? *rufa*), grown in the Sydney Botanic Gardens from seed imported from Nairobi. Although a species other than *H. filipendula* is concerned here, the range of the latter in Africa does cover the territory from which the Sydney grass was obtained. *Hyparrhenia filipendula*, if it had been introduced in the Sydney or Perth areas, might have established itself there in waste areas where it would be free from competition from native plants. A final point against the possibility of introduction of the grass from Africa is that *Hyparrhenia filipendula* does not occur south of latitude 30° S., and so is not likely to have been brought over by travellers who visited the Cape of Good Hope area on their way to Australia in the late eighteenth or early nineteenth centuries. Since *Hyparrhenia filipendula* was not found in the areas serving as bases for those who originally explored or settled in other parts of the continent, it is very likely that the record of the grass by Leichhardt in " Eastern Australia " represents the collection of a naturally occurring species. The possibility of the introduction of *Hyparrhenia filipendula* from south-east Asia direct to the settlement around Moreton Bay prior to 1843 is remote.

In south-eastern Queensland, a smut, *Ustilago hyparrheniae* Hopkins is common on *Hyparrhenia filipendula*. This smut was described from the same host from Southern Rhodesia, and a Queensland specimen sent to Southern Rhodesia was reported as being identical with the type collection (Bates 1948). If seed of this grass had been accidentally introduced to this country from Africa in the past, one might reasonably suppose that the smut had come with it.

The occurrence of ergot on *Hyparrhenia* in Africa has been noted above, but the species of *Claviceps* affecting the genus there has not yet been determined. Nor is the species of *Claviceps* affecting *Hyparrhenia* in South America known. While these ergots are undetermined, one cannot say whether all the ergot diseases of *Hyparrhenia* are the same. But to assume that the Australian ergot has been brought here with an accidental introduction of seed would suppose a rather unlikely series of events, the carriage of sclerotia, with their subsequent development and release of ascospores at a time when the introduced host was flowering. This view is put forward despite the presence in Australia of *Claviceps purpurea* and *Claviceps paspali*, neither of which is indigenous to this country. The former was introduced in the nineteenth century, probably with cereal grain or with seed of pasture grasses (possibly in both ways). In any case, an abundance of hosts of more than one species would be available to any germinating sclerotia, for native grasses as well as introduced plants are recorded as hosts of this ergot in southern Australia. *Claviceps paspali* appears to have been introduced much later. It has been widespread and very common on several species of *Paspalum* in eastern Australia since the summer of 1935-36, when it was observed for the first time. The quick development of epiphytotics of ergot in *Paspalum* every year now in coastal Queensland indicates how well local conditions suit this ergot. The first sclerotia to germinate after their introduction (probably in 1935) had available an abundance of *Paspalum dilatatum* which flowers profusely, and the initial infections should not have been difficult to accomplish. Plants of *Hyparrhenia filipendula*, unlike *Paspalum dilatatum* the chief host of *Claviceps paspali*, are not massed in pure stands over large areas, and are not common as weeds of waste places. Nor is any alternative host of *Claviceps inconspicua* known. The possibility of infection of *Hyparrhenia* by ascospores from sclerotia introduced by chance at any time is very much less than for the hosts of *Claviceps purpurea* and *Claviceps paspali*. Furthermore, all observed occurrences of *Claviceps inconspicua* on *Hyparrhenia* have been light infections, indicating that environmental conditions do not usually favour epiphytotics of this ergot, and that infection under prevailing circumstances is relatively difficult. The enphytotic state of this ergot disease may perhaps be regarded as the result of a long-standing association of host and parasite in this country.

The mycological evidence bearing on the question of whether *Hyparrhenia filipendula* is a native or an introduced species in Australia is divided. The introduction of a smut with the seed is feasible, but the probability of the introduction of an ergot specific to this host is not easy to accept. One might postulate development of an ergot species, specific to *Hyparrhenia filipendula*, from some indigenous Australian ergot. *Claviceps inconspicua*, morphologically, has much in common with *Claviceps pusilla*, an ergot which infects a wide range of genera in the sub-tribe Andropogoninae, and with *Claviceps annulata*, an ergot infecting *Eulalia* of the sub-tribe Saccharinae. Possibly *Claviceps inconspicua* and *Claviceps annulata* are Australian variants of the more widely distributed *Claviceps pusilla*. If one rejects the hypothesis that *Claviceps inconspicua* is an evolutionary product of the past century, specific to *Hyparrhenia filipendula* and developed since the time of that grass's introduction to Australia, the above proposition may still be valid. The host *Hyparrhenia filipendula* is known from the Philippines (Merrill 1925) and from Ceylon, India and Malaya (Stapf 1934). Possibly it is a species of wide natural distribution, extending from Africa, through Asia, to Australia. If it is a grass of long-standing occurrence in Australia, an explanation of the presence here of its ergot, having affinities with other indigenous ergots, can be found.

The ecological, phytogeographical and mycological evidence presented here supports the theory that *Hyparrhenia filipendula* is a species native to Australia. If one accepts the indigenous nature of the host, then *Claviceps inconspicua* can be regarded as an ergot indigenous to Australia.

ACKNOWLEDGMENTS.

I wish to thank Mr. S. T. Blake for his assistance in the preparation of this paper by discussion with me of the plant distribution problem involved and by making available various records of the occurrence of *Hyparrhenia filipendula* in Australia ; and Professor D. A. Herbert whose constructive criticism of the theories put forward has been most helpful. Financial assistance for this work was granted by the University of Queensland Commonwealth Research Projects Committee, to whom the author is grateful.

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REVISION OF *BREGMACEROS* WITH DESCRIPTIONS OF LARVAL STAGES FROM AUSTRALASIA

BY IAN S. R. MUNRO, M.SC., Division of Fisheries, Commonwealth Scientific and Industrial Research Organization.

(WITH TEN FIGURES IN THE TEXT).

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SUMMARY.

Six species of the genus *Bregmaceros* are recognised, including *B. rarisquamosus* sp. nov. from New Guinea and the Solomon Islands. All are described, references to species listed, and the distribution of the genus is given. On the basis of larval and post-larval stages, *B. macclellandi* is recorded from eastern Australia and *B. japonicus* and *B. nectabanus* are recorded from eastern Australia and New Guinea. The larval and post-larval stages are described and figured.

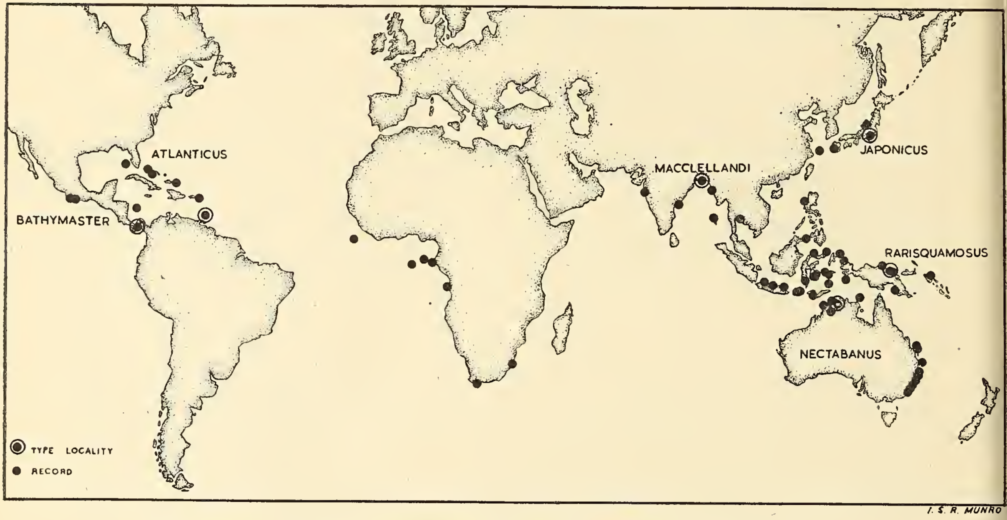
INTRODUCTION.

A large series of plankton collections obtained off the eastern coast of Australia during the period 1938 to 1942 by F.R.V. " Warreen," fisheries research vessel of the Commonwealth Scientific and Industrial Research Organization, has yielded seventy-two larval fishes of the genus *Bregmaceros*. F.R.V. " Stanley Fowler," another survey vessel of this organization, obtained by means of a submarine lamp six specimens from Northern Territory and North-Western Australia in 1949. During 1948 to 1950, M.V. " Fairwind," fisheries survey vessel of the Department of External Territories, obtained by means of a submarine lamp fourteen additional specimens in Papua, New Guinea, and the Solomon Islands.

The identification of Australasian material has necessitated a review of the literature dealing with all described forms. Type material has not been accessible, but the differences between species have been obtained from published descriptions and figures. Compilations of adult characters and complete lists of references have been drawn up for each of the six species recognised. A revised key has been prepared to distinguish at least the adults of the accepted species. The distribution of the genus has been summarised by means of a map (Text Fig. 1).

The genus *Bregmaceros* was proposed by Thompson (1840, p. 184) for *B. macclellandi* from the Ganges River. Günther (1889, p. 24) rightly placed *Calloptilum mirum* Richardson (1843, p. 46) from China Seas and *Asthenurus atripinnis* Tickell (1865, p. 32) from Burma (Akyab) in the synonymy of *B. macclellandi*. Five other forms have since been described, some of which have been considered worthy only of sub-specific or varietal rank. These are *B. atlanticus* Goode and Bean (1886, p. 165) from the West Indies, *B. bathymaster* Jordan and Bollman (1889, p. 173) from the Gulf of Panama, *B. longipes* Garman (1899, p. 191) from western Mexico, *B. japonicus* Tanaka (1908, p. 42) from Japan, and *B. nectabanus* Whitley (1941, p. 25) from Darwin, northern Australia.

The status of the various forms is poorly understood. Parr (1931, p. 48) recognised the need for a revision and presented a key to distinguish four species. On the other hand, Norman (1930, p. 339) followed the simpler course. By ignoring differences, he united all Atlantic, Pacific and Indian Ocean material in a single species. This view is not accepted as larval material from eastern Australia is composed of three species, and three species occur in adjacent localities in New Guinea. This immature material serves to show that authors have been in error in assuming that variations in pigmentation are due to different stages in development of the one species.



TEXT FIG. 1 : Distribution of the genus *Bregmaceros* Thompson.

KEY TO SPECIES.

I. Less than 70 scales in longitudinal series :

1. Ventral fins half body length without caudal ; less than 50 scales in longitudinal series ; body and fins pale and hyaline .... *B. rarisquamosus*

2. Ventral fins two-thirds body length without caudal ; more than 50 scales in longitudinal series ; body and fins in part dusky or with numerous black dots :

A. 10 scales in transverse series :

a. Eye 3.0 in head, nearly twice snout ; interorbital less than eye ; body silvery with rows of black dots near bases of dorsal and anal fins .... *B. bathymaster*

aa. Eye 3.5 to 4.0 in head, equal to or shorter than snout ; interorbital conspicuously wider than eye ; body uniformly dark ... *B. atlanticus*

AA. 14 to 16 scales in transverse series ; body silvery, minutely dotted with brown ; at least dorsal fins black .... *B. macclellandi*

II. More than 70 scales in longitudinal series :

1. 13 or 14 scales in transverse series ; eye less than interorbital and snout ; depth more than 8 in length without caudal, less than height of anal rays ; body dusky ; fins dark .... *B. japonicus*

2. 17 scales in transverse series ; eye greater than interorbital and snout ; depth less than 7 in length without caudal, nearly equal to height of anal rays ; body pale with brown dorso-lateral stripe ; fins pale .... *B. nectabanus*

BREGMACEROS RARISQUAMOSUS sp. nov.

(Fig. 10)

D. (11-14) + (7-12) + (14-18), (36-39). A. (12-15) + (7-12) + (15-18), (38-40). P. 15-16. C. 24-26. Lat. sc. 43-50. Trans. sc. 10-12. Depth 5.0 to 6.1, head 5.1 to 5.6 in body length without caudal. Eye very large, 2.7 to 3.5 in head, 0.25 to 0.5 greater than snout, 1.3 to 1.7 in interorbital. Maxilla extends to below the posterior third of the eye, 1.9 to 2.1 in head. Nuchal appendage equal to, or 0.2 greater than head. Dorsal fin inserted slightly in advance of the anal fin. Longest anal ray 0.9 to 1.1 in head. Ventrals 0.45 to 0.5 of body length without caudal, extending to half way along the anterior raised portion of the anal fin. Pectorals 1.4 to 1.6 in head. (See Table I).

Eye black. Flesh glassy transparent in life, white when preserved. Body ornamented with large stellate melanophores. An hour-glass-shaped patch present on the postero-dorsal aspect of the head between the eyes and the nuchal appendage consisting of five small clusters, the three anterior composed of large melanophores and the two posterior of small spidery melanophores. On the dorso-lateral aspect of each side of the body is a weak, sub-horizontal stripe, extending from the upper angle of the operculum to the caudal peduncle, composed of two or more series of melanophores. The cells are largest under the posterior elevated part of the dorsal fin, and smallest under the low middle section of the dorsal fin. The vertebral column is heavily pigmented with large internal melanophores. A single series extends along the ventral mid-line of the trunk between the origins of the ventral and anal fins. Fins hyaline. Rays of posterior part of dorsal fin lightly dotted with minute melanophores.

This species is closest to *B. nectabanus* Whitley. Both species are similar in coloration, but fin and scale counts differ considerably. The New Guinea species has fewer dorsal and anal rays, and considerably less horizontal and vertical tracts of scales. It has a larger eye and shorter ventral fins.

Based on two sexually mature females (28.5, 33.3 millimetres) from Bostrem Bay (Sek Harbour), north coast of New Guinea (27.12.48) and three young adults (23.0, 24.5, 25.5 millimetres) from Port Moresby Harbour, Papua (2.7.48). Post-larval stages were obtained at Madang Harbour, north coast of New Guinea and Kieta Harbour, eastern Bougainville, Solomon Islands. All were attracted to the surface at night using a submarine lamp. The material was collected on the M.V. " Fairwind." The largest adult female from Bostrem Bay is selected as holotype and deposited at the Marine Biological Laboratory, Division of Fisheries, Commonwealth Scientific and Industrial Research Organization.

Larval Stages :—Five post-larval stages are referred to this species.

Length	Locality	Date	Dorsal Fin Rays	Anal Fin Rays
16.4 mm.	Kieta, Bougainville ...	21.10.49	13+12+14, (39)	14+ 8+17, (39)
17.0 mm.	Kieta, Bougainville ...	22.10.49	14+ 9+15, (38)	15+ 9+15, (39)
18.2 mm.	Kieta, Bougainville ...	21.10.49	14+12+14, (38)	12+ 8+18, (38)
19.7 mm.	Kieta, Bougainville ...	22.10.49	13+ 7+18, (38)	14+10+15, (39)
21 5 mm.	Madang, New Guinea ...	26.11.49	13+11+15, (39)	12+10+18, (40)

TABLE I.—FIN RAY COUNTS, SCALE COUNTS AND BODY PROPORTIONS OF FIVE ADULT INDIVIDUALS OF *Bregmaceros varisquamosus*.

	A	B	C	D	E
Locality	Port Moresby	Port Moresby	Port Moresby	Bostrem Bay	Bostrem Bay
Total Length	25.5 mm.	23.0 mm.	24.5 mm.	33.3 mm.	28.5 mm.
Dorsal Fin	11 + 9 + 16, (36)	12 + 9 + 15, (36)	11 + 10 + 15, (36)	12 + 12 + 14, (38)	14 + 8 + 17, (39)
Anal Fin	13 + 11 + 16, (40)	13 + 10 + 15, (38)	13 + 10 + 15, (38)	12 + 12 + 15, (39)	14 + 7 + 17, (38)
Lateral Scales	50	48	46	44	43
Transverse Scales	11	12	11	10	10
Body/Head	5.4	5.6	5.2	5.1	5.5
Body/Depth	6.1	6.0	6.1	5.0	5.7
Head/Eye	3.3	3.5	3.3	2.7	2.9
Eye/Snout	1.5	1.25	1.5	1.5	1.5
Interorbital/Eye	1.7	1.3	1.4	1.3	1.3
Head/Pectoral Fin	1.5	1.5	1.5	1.4	1.6
Head/Maxilla	2.0	2.0	2.0	1.9	2.1
Nuchal Appendage/Head	1.0	1.1	1.0	1.2	1.1
Head/Anal Fin Rays	1.1	0.9	1.1	1.0	1.0
Body/Ventral Fin Rays	2.3	2.1	2.3	2.2	2.3

16.4 *to* 21.5 *millimetre post-larvae.*—Most of the adult facies present. Depth 6.0 to 7.0, head 4.5 to 5.5 in body length without caudal. Eye relatively smaller than in adults, 4.0 to 4.5 in head, equal or 0.2 greater than snout, 0.2 less than to 0.2 greater than interorbital. Maxilla extends to below posterior border of pupil. Nuchal appendage equal to or 0.2 less than head, not reaching origin of dorsal fin. Dorsal fin inserted above or slightly in advance of anal fin. Ventrals 0.4 to 0.45 of body length without caudal. Pectorals 0.5 to 0.7 of head length. Scales present but difficult to count; one example from Madang has 11 transverse and 49 lateral series. Flesh white in preserved condition, transparent in life. Pigmentation similar to adults but melanophores are smaller and less numerous. The dorso-lateral stripe is composed of a single series of small melanophores restricted to the caudal region. Pigmentation is insufficient to distinguish these post-larvae from those of *B. nectabanus* of similar size and development.

BREGMACEROS NECTABANUS Whitley.

Bregmaceros nectabanus Whitley 1941, p. 25, fig. 18 (Darwin, Northern Territory, Australia—Type locality).

Bregmaceros macclellandi (*non* Thompson) Kent 1889, p. 240 (Cambridge Gulf, NW. Australia). McCulloch 1926, p. 29 (Darwin). Paradice and Whitley 1927, pp. 81, 97 (Darwin).

D. (12-18) + (9-16) + (17-23), (40-55). A. (15-19) + (9-12) + (17-24), (42-53). C. 28. Lat. sc. 70-74. Trans. sc. 17-18. Depth 6.1 to 6.6, head 5.2 to 5.9 in body length without caudal. Eye small to moderate, 3.4 to 3.8 in head, equal or 0.1 greater than snout and equal or 0.2 greater than interorbital. Maxilla reaches to below posterior border of eye, 1.6 to 2.0 (1.8) in head. Nuchal appendage 0.1 to 0.4 longer than head. Dorsal fin inserted slightly in advance of the anal fin. Longest anal rays 0.8 to 0.9 of head length. Ventrals 0.5 to 0.6 of body length without caudal, extending to end of anterior raised portion of anal fin. Pectorals 1.4 to 1.7 in head. (See Table II).

Eye black. Flesh yellowish-white in spirits, probably transparent in life. Body ornamented with large, indistinct stellate melanophores. A group is present on the postero-dorsal aspect of the head. An indistinct brownish stripe composed of one or two series of melanophores extends along each side from the upper angle of the operculum to the caudal peduncle. The fins are hyaline. The pigmentation is similar to that of *B. rarisquamosus* but the melanophores are smaller and more numerous.

Based on the holotype (Australian Museum Reg. No. IA 1719) collected at Darwin in 1923 by Dr. W. E. J. Paradice during survey work by H.M.A.S. " Geranium." Additional adult material was obtained by F.R.V. " Stanley Fowler " in Northern Territory and North-Western Australia. This consists of four specimens from Marchinbar Island, Wessel Group (18.10.49), one from Timor Sea, 30 miles WNW. of Charles Point, Northern Territory (22.9.49) and one from Mission Bay, Napier Broome Bay, Western Australia (11.12.49). All were attracted to the surface at night by a submarine lamp. Occurrence of this species on the north coast of New Guinea is based on three post-larval stages from Wewak Harbour collected on 23.11.49 from M.V. " Fairwind " with the aid of a submarine lamp. The distribution is also extended to the coasts of Queensland and New South Wales, based on sixty-four

TABLE II.—FIN RAY COUNTS, SCALE COUNTS AND BODY PROPORTIONS OF SEVEN INDIVIDUALS OF *Bregmaceros nectabanus*.

	Holotype	A	B	C	D	E	F
Locality ...	Darwin	Wessel Is.	Wessel Is.	Wessel Is.	Wessel Is.	Timor Sea	Napier Broome Bay
Total Length ...	32.0 mm.	54.0 mm.	49.8 mm.	39.5 mm.	30.5 mm.	30.0 mm.	34.0 mm.
Dorsal Fin ...	14+16+20, (50)	17+15+23, (55)	17+12+22, (51)	15+15+21, (51)	16+12+17, (45)	12+10+18, (40)	15+16+22, (53)
Anal Fin ...	19+11+23, (53)	16+12+22, (50)	18+11+24, (53)	17+11+22, (50)	15+10+17, (42)	16+10+17, (43)	17+11+24, (52)
Lateral Scales ...	73	74	74	73	70	70	71
Transverse Scales ...	17	18	16	17	17	17	18
Body/Head ...	5.8	5.9	5.5	5.5	5.5	5.2	5.4
Body/Depth ...	6.5	6.6	6.5	6.5	6.2	6.1	6.6
Head/Eye ...	3.7	3.6	3.7	3.8	3.8	3.6	3.4
Eye/Snout ...	1.0	1.0	1.1	1.0	1.0	1.0	1.1
Eye/Interorbital	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Head/Pectoral Fin	1.7	1.5	1.5	1.5	1.4	1.4	1.5
Head/Maxilla ...	1.8	1.6	1.8	1.8	1.8	2.0	1.8
Nuchal Appendage/Head ...	1.1	1.2	1.3	1.4	1.2	1.3	1.3
Head/Anal Fin Rays	1.2	1.2	1.2	1.1	1.1	1.2	1.1
Body/Ventral Fin Rays ...	1.6	1.7	1.8	2.0	2.2	2.0	1.8

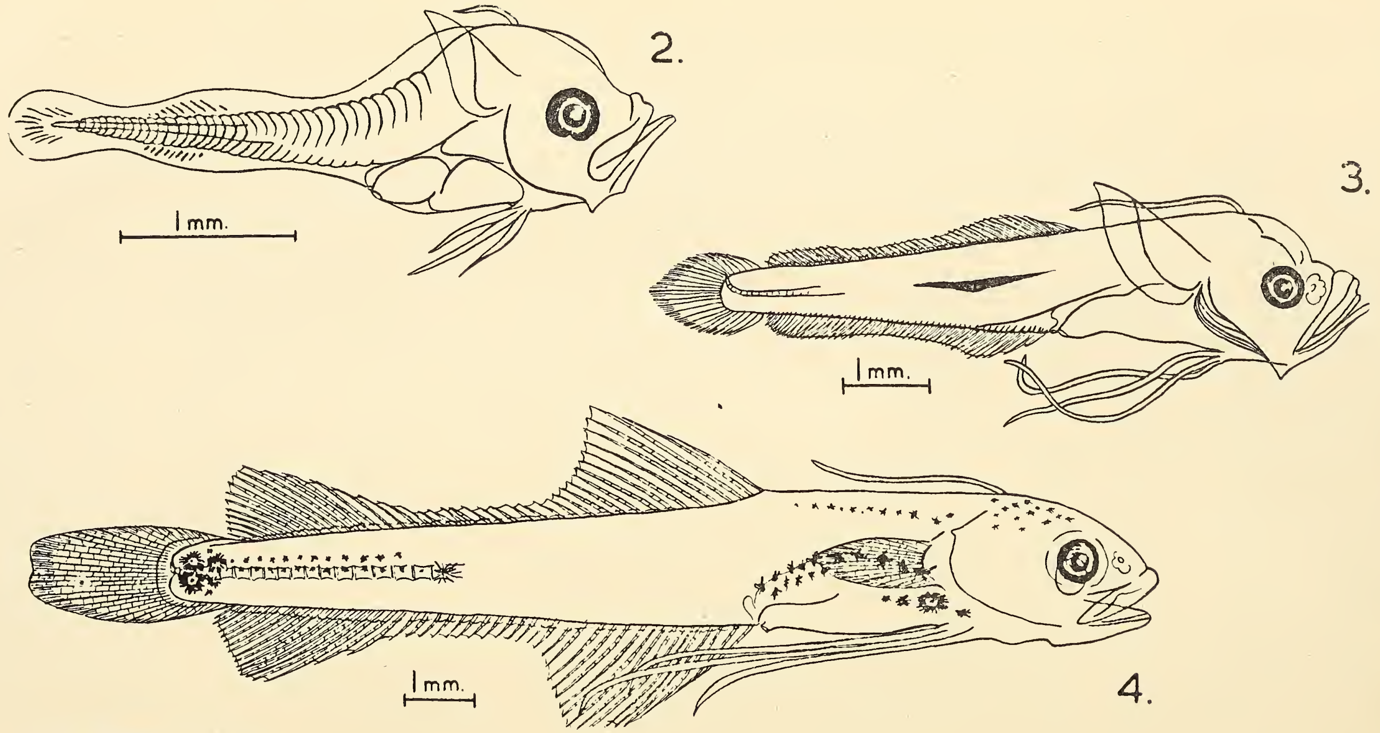
post-larval stages from plankton collections made by F.R.V. " Warreen " in the vicinities of Lady Elliot Island, Break-Sea Spit, Cape Moreton, Cape Byron, Coff's Harbour, Trial Bay, Crescent Head, Crowdy Head, Port Stephens, Sydney Heads, Jervis Bay, and Bermagui.

Larval Stages.—The immature specimens from Wewak measure 16.5, 19.0 and 19.5 millimetres respectively. The sixty-four planktonic specimens obtained by F.R.V. " Warreen " vary in length from 2.1 to 21.7 millimetres.

No. of Speci-mens	Size Range	Station	Position	Date	Net	Depth
1	16.8 mm.	40A/38	26° 54′ S. 153° 24′ E.	20.9.38	N70	25 m.
12	8.4-21.7 mm.	,,	,, ,,	,,	N200	0 m.
1	9.1 mm.	46/38	24° 20′ S. 153° 02′ E.	19.9.38	N70	25 m.
7	4.2-9.8 mm.	,,	,, ,,	,,	N200	0 m.
1	14.0 mm.	48/38	27° 02′ S. 153° 45′ E.	21.9.38	N100	0 m.
2	14.7-16.8 mm.	49/38	28° 37′ S. 153° 42′ E.	21.9.38	N200	0 m.
1	11.9 mm.	52/38	30° 16′ S. 153° 32′ E.	23.9.38	N100	0 m.
1	9.1 mm.	128/39	32° 37′ S. 152° 22′ E.	3.5.39	N100	25 m.
4	4.2-6.3 mm.	133/39	28° 38′ S. 153° 43′ E.	6.5.39	N70	25 m.
2	8.0-10.8 mm.	,,	,, ,,	,,	N100	25 m.
3	15.4-16.1 mm.	136/39	27° 03′ S. 153° 31′ E.	14.5.39	N70	25 m.
1	16.8 mm.	,,	,, ,,	,,	N100	0 m.
7	14.7-16.8 mm.	,,	,, ,,	,,	N100	25 m.
1	11.9 mm.	137/39	30° 55′ S. 153° 08′ E.	16.5.39	N70	25 m.
1	14.0 mm.	,,	,, ,,	,,	N100	25 m.
3	16.1-19.6 mm.	139/39	31° 51′ S. 152° 50′ E.	17.5.39	N70	25 m.
9	14.0-18.9 mm.	,,	,, ,,	,,	N100	25 m.
1	8.4 mm.	196/39	24° 15′ S. 153° 03′ E.	7.7.39	N200	0 m.
2	2.1-4.2 mm.	203/39	Off Crescent Head ...	18.7.39	N100	9-200 m.
1	3.9 mm.	31/40	24 miles SE. of Sydney Heads	25.4.40	N70	0-200 m.
1	7.0 mm.	33/40	15 miles ENE. of Jervis Bay ...	30.4.40	N70	0-200 m.
1	4.9 mm.	,,	,, ,,	,,	N100	0-200 m.
1	11.2 mm.	73/41	12 miles ENE. of Bermagui ...	12.10.41	N100	0-50 m.

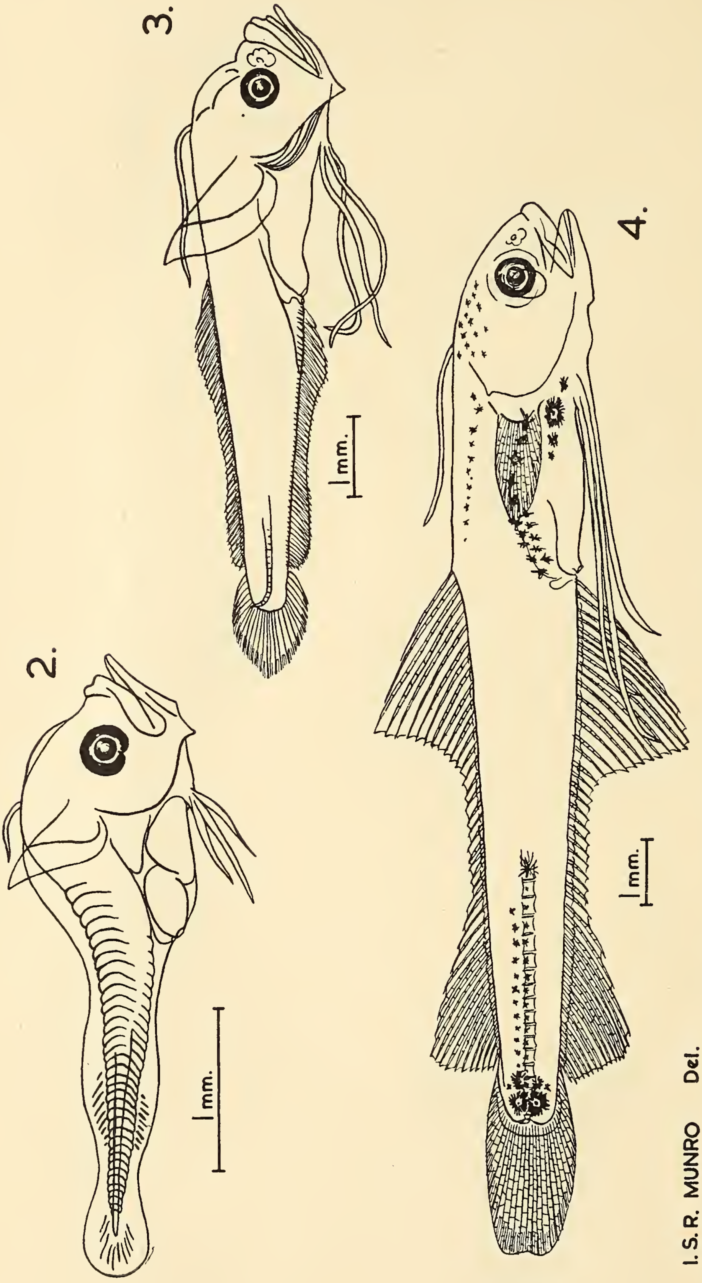
3.9 *millimetre post-larva.*—(Fig. 2). Yolk completely absorbed. Mouth and intestinal tract functional. Body short relative to depth. Head and visceral cavity disproportionately large. Eye black ; choroid fissure incompletely closed. Maxilla extends to below middle of pupil. 39 or 40 myomeres. Fins little differentiated. Nuchal appendage present. Ventral fins represented by rudiments divided into 3 unequal rami. Pectoral present, consisting of an undivided fold and a muscular base. Dorsal, anal and caudal fins represented by a continuous fin fold in which rays of each fin are incompletely differentiated. Pigment entirely lacking.

8.0 *millimetre post-larva.*—(Fig. 3). Considerable increase in development of body form and differentiation of fins. Body more elongate than in 3.9 millimetre larvae. Head 4.5, depth 5.0 in body length without caudal. Eye has lost choroid fissure ; 3.5 in head, slightly less than snout. Maxilla extends to below pupil. Branchiostegal rays plainly visible. Pectoral fin 0.75 of head length. Nuchal appendage



I. S. R. MUNRO Del.

Text Figs. 2-4.—Fig. 2: *Bregmaceros nectabanus* Whitley, 3.9 millimetre postlarva from "Warreen" station 31/40 (off Port Hacking). Fig. 3: *Bregmaceros nectabanus* Whitley, 8.0 millimetre postlarva from "Warreen" station 133/39 (off Cape Byron). Fig. 4: *Bregmaceros nectabanus* Whitley, 16.1 millimetre postlarva from "Warreen" station 136/39 (off Cape Moreton).



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Text Figs. 2-4.—Fig. 2: *Bregmaceros nectabanus* Whitley, 3.9 millimetre postlarva from " Warreen " station 31/40 (off Port Hacking). Fig. 3: *Bregmaceros nectabanus* Whitley, 8.0 millimetre postlarva from " Warreen " station 133/39 (off Cape Byron). Fig. 4: *Bregmaceros nectabanus* Whitley, 16.1 millimetre postlarva from " Warreen " station 136/39 (off Cape Moreton).

extends to origin of dorsal fin ; slightly exceeds head length. Ventral fin rays (3) extend to the end of anterior part of anal fin ; reach 0.4 of the body length without caudal. Rays completely differentiated in all fins. Dorsal and anal separated from caudal. Caudal rounded or slightly pointed. In specimen figured D. 43, A. 45, C. 26. Anal and dorsal fins not differentiated into high and low parts. Eye black. Body otherwise unpigmented. First appearance of chromatophores is at 9.0 millimetres, when a few large stellate melanophores develop on the caudal base.

16.1 *millimetre post-larva.*—(Fig. 4). Typical of series which range from 14.0 to 21.7 millimetres. Most of adult facies present. Head 4.8, depth 7.0 in body length without caudal. Eye small, 4.5 in head, less than snout or interorbital ; equipped with an adipose lid and pigmented black. Maxilla extends to below posterior border of pupil. Nuchal appendage equal to head length, does not quite reach to origin of dorsal fin. Ventrals reach anterior tip of anal but less than 0.5 of body length without caudal. Anal and dorsal fins with elevated anterior and posterior sections as in adults. In specimen figured, D. 14 + 11 + 17, (42), A. 17 + 12 + 18, (47). In the Wewak specimens D. 18 + 12 + 17, (47) ; 14 + 10 + 18, (42) ; 14 + 10 + 19, (43) and A. 18 + 9 + 21, (48) ; 16 + 10 + 18, (44) ; 16 + 10 + 17, (43). Caudal now slightly emarginate. Pectorals 0.6 of head length, with 15 or 16 rays. Scales present but difficult to count ; one example has 17 transverse and 70 lateral series. Body white or pinkish in preserved condition, probably transparent in life. Several series of stellate melanophores present. A patch of small melanophores on postero-dorsal aspect of head. An oblique row of single series extends from angle of operculum to origin of dorsal fin. A few large melanophores between bases of pectoral and ventral fins. An internal cluster lines the upper surface of the visceral cavity. Four to six large, stellate chromatophores on caudal peduncle. A single series continues forward above the lateral mid-line to the origin of the posterior elevated portion of the dorsal fin. Some internal melanophores invest the vertebral column in the caudal region. All fins hyaline.

BREGMACEROS MACCLELLANDI Thompson.

Bregmaceros macclellandi Thompson (*ex* Cantor's MS) 1840, p. 184, fig. 6 (Ganges Delta). Günther 1862, p. 368 (China Sea ; Philippine Islands). Day 1865, p. 171 (Malabar and Bengal Coasts). Day 1875-1878, p. 418 (India). Day 1889, p. 433, fig. 151 (Bombay Coast, Burma, Andaman Islands). Günther 1889, pp. 22-25, pl. 3, figs. A, B (Indian Ocean, Pacific Ocean, Amboina, Indian Archipelago). Alcock 1893, p. 181 (Bay of Bengal). Alcock 1899, p. 75 (Bay of Bengal, Andaman Islands, Malabar Coast). Weber 1913, p. 174 (Madura Sea, Bima Bight, Molo Straits, Borneo Bank, N. Celebes (Kwandang Bay), Molucca Passage, Halmahera Sea, Waigeu, W. Ceram (Kawa Bay), Sula-Besi (Sanana Bay), Banda Sea, Wowomi-Buton, Buton Straits, S. Celebes-Saleyer, Ambon, Kei Islands, Savu Sea, N. Soembawa (Salah Bight), Flores Sea). Gilchrist and Thompson 1914, p. 87 (Cape Natal). Gilchrist and Thompson 1917, p. 320. Barnard 1925, p. 325 (Agulhas Bank ; Natal). Weber and Beaufort 1929, p. 6, fig. 2 (N. Java, Samarang Road). Smith 1933, p. 53 (Siam). Delsman and Hardenberg 1934, p. 32, fig. 23.

Calloptilum mirum Richardson 1843, p. 95, pl. 46, figs. 4-7 (China Seas).

Asthenurus atripinnis Tickell 1865, p. 32, pl. 1 (Bay of Bengal off Akyab).

Bregmaceros atripinnis Day 1869, p. 522. Day 1875-1878, p. 418, pl. 91, fig. 1.

Bregmaceros sp. Wood-Mason and Alcock 1891, p. 29 (Bay of Bengal, off mouth of Kistna River).

D. (15-20) + (10-17) + (13-22), (41-57). A. (18-22) + (10-16) + (15-26), (43-63). Lat. sc. 54-71. Trans. sc. 13-16. Depth 5.5 to 7.0, head 5.5 to 7.0 in body length without caudal. Eye moderate, 3.5 to 4.5 in head, equal to or slightly less than interorbital and snout. Maxilla extends to below middle of eye, 2.1 to 2.5 in head. Nuchal appendage 0.4 to 0.5 longer than head. Dorsal fin inserted slightly in advance of anal fin. Longest anal rays 0.25 greater than head. Ventrals 0.63 of body length without caudal, extending past end of first section of anal fin. Pectorals equal to head without snout. Nape and back brown. Cheeks and flanks silvery or greenish, minutely dotted with small brown chromatophores. Dorsal, pectoral, anal and caudal fins blackish. Ventrals whitish. In young, fins hyaline with peripheral portions blackish. Pharyngial and abdominal epithelia black. (Compiled).

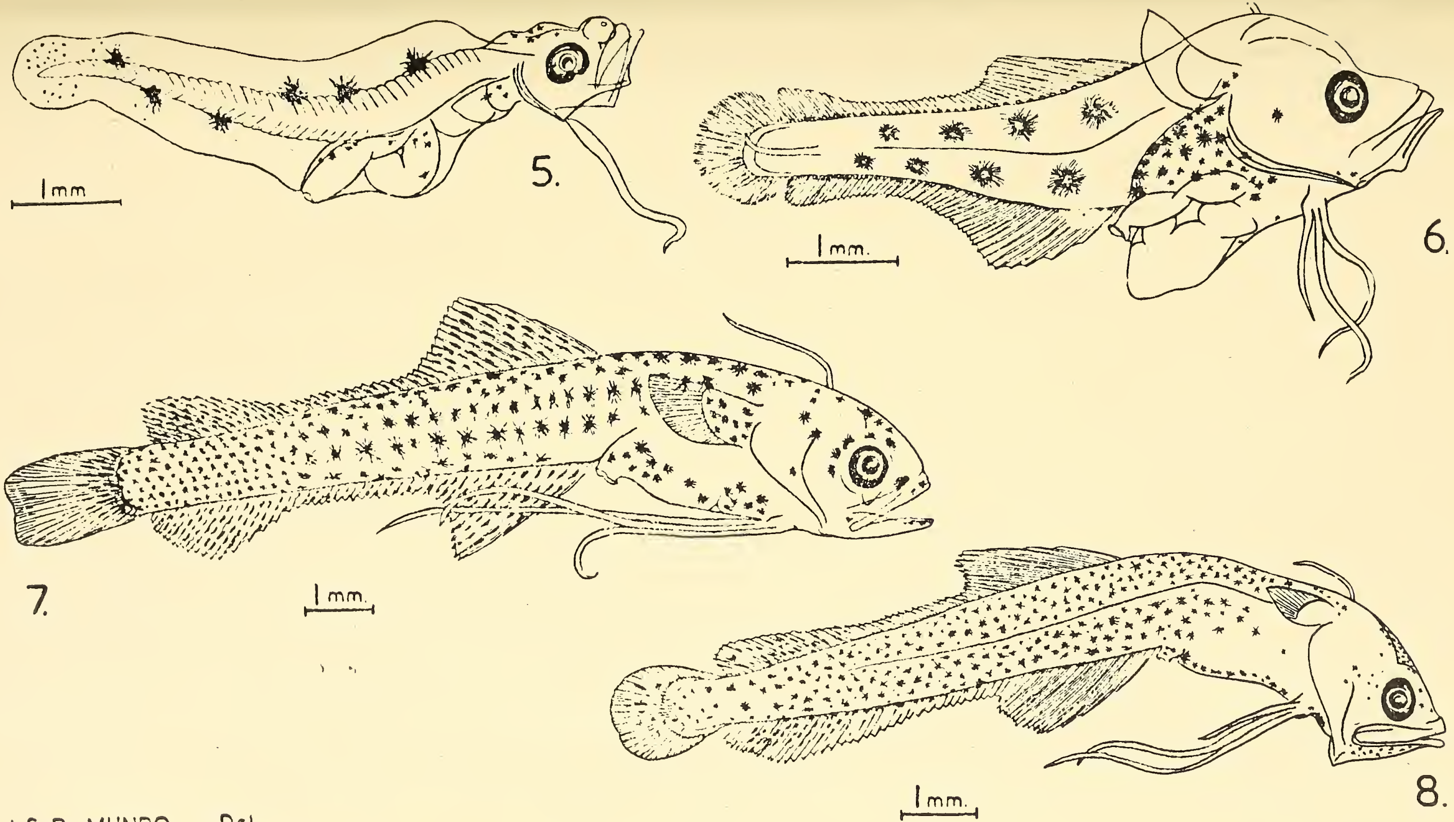
The Australian Museum has a single example (Reg. No. B 7536) from Bombay, 79 millimetres total length, procured from Dr. Francis Day in 1885 as *B. atripinnis*. D. 20 + 19 + 23, (62). A. 20 + 16 + 25, (61). Lat. sc. 76. Trans. sc. 14. Head 6.5, depth 6.5 in body length without caudal. Eye 3.0 in head, equal to interorbital, 1.4 in snout. Maxilla extends to below posterior edge of pupil, 2.0 in head. Nuchal appendage twice head. Dorsal fin inserted slightly in advance of anal fin. Longest anal rays 0.25 greater than head. Ventrals 0.5 of body length without caudal. Pectorals 0.9 of head length. Colour brownish ; skin minutely dotted with brown specks, about 3 to 5 under each scale. Pectoral and caudal fin dusky. Dorsal dark distally. Ventrals and anal white. Pharyngial epithelium black.

Distributed throughout the Indo-Pacific, including eastern Africa, India, Burma, Andaman Islands, China, Philippine Islands and Netherlands East Indies. Former records from Australia (Darwin and Cambridge Gulf) refer to *B. nectabanus*. Although adults are unknown from Australian seas, larvae have been obtained in plankton nets by F.R.V. " Warreen " from Queensland (Break-Sea Spit) and New South Wales (Coff's Harbour and Narooma).

Larval stages.—1 prolarva and 4 post-larvae are included in the plankton collections and they are identified as *B. macclellandi* on the basis of pigmentation and body proportions.

Specimens	Station	Position	Date	Net	Depth
11.2 mm. 13.6 mm.	52/38	30° 16′ S. 153° 32′ E.	23.9.38	N100	0 m.
12.6 mm	144/39	36° 15′ S. 150° 24′ E.	31.5.39	N200	100 m.
6.6 mm.	195/39	24° 21′ S. 153° 22′ E.	7.7.39	N100	0-200 m.
5.8 mm.	30/40	30° 18′ S. 153° 32′ E.	22.4.40	N100	0-200 m.

5.8 *millimetre prolarva.*—(Fig. 5). Yolk almost completely absorbed Mouth large, functional. Intestine of several clearly defined coils. Eye black, choroid fissure not closed. Pectoral and ventral fin rudiments.



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Text Figs. 5-8.—Fig. 5 : *Bregmaceros macclellandi* Thompson, 5.8 millimetre prolarva from " Warreen " station 30/40 (off Coff's Harbour). Fig. 6 : *Bregmaceros macclellandi* Thompson, 6.6 millimetre postlarva from "Warreen" station 195/39 (off Break-Sea Spit). Fig. 7 : *Bregmaceros macclellandi* Thompson, 13.6 millimetre postlarva from "Warreen" station 52/38 (off Coff's Harbour). Fig. 8 : *Bregmaceros japonicus* Tanaka, 11.5 millimetre postlarva from " Warreen " station 50/38 (off Cape Byron).

present. Unpaired fins represented by a continuous fin fold. No fin rays differentiated. Nuchal appendage either undeveloped or detached. Ventral fins represented by a single elongate process, not differentiated into rays. About 45 myomeres. Four dorsal and two ventral large, stellate melanophores at junction of myomeres and fin folds. Smaller melanophores on caudal part of fin fold, fleshy base of pectoral rudiments, intestinal loops and supracephalic sinus. General facies of this prolarva, especially the elongate ventral fin rudiment, indicate identity with the genus *Bregmaceros*. The large melanophores which are carried over into later stages, indicate this particular species.

6.6 *millimetre post-larva*.—(Fig. 6). Body short relative to depth. Head and visceral cavity disproportionately large. Eye lacking choroid fissure ; black. Operculum and branchiostegals clearly differentiated. All radials of dorsal, caudal and anal clearly visible. D. 50. A. 52. C. 26. Caudal fin rounded. Both dorsal and anal fins elevated anteriorly and posteriorly. Nuchal appendage present but probably broken. Ventrals divided into 3 unequal rays. A reticulum of small, stellate melanophores invests the dorsal aspect of visceral cavity. A few are scattered over cheeks and base of pectoral fin. Four dorsal and four ventral giant, stellate melanophores on trunk. They are internal to the musculature and probably represent those on the fin folds of 5.8 millimetre larvae.

11.2 *to* 13.6 *millimetre post-larvae*.—(Fig. 7). Advanced larvae measuring respectively 11.2, 12.6 and 13.6 millimetres, agree closely in all characters and appear to be later stages of the 5.8 and 6.6 millimetre larvae described above. Body form more closely approaches that of adult *B. macclellandi*. Head 4.5, depth 5.75 in body length without caudal. Eye 4.0 in head, equal to snout, slightly less than interorbital. Maxilla extends to slightly behind centre of eye. D. 47-48. A. 10 + 22 + 17, (49). C. 30, slightly emarginate. Ventrals 0.5 of body length without caudal. Pectorals 0.6 of head length ; with 15 rays. Scales developed in largest specimen ; 14 transverse series ; lateral series indeterminate. Body pigmented with numerous small, stellate melanophores as noted by previous authors in the young of *B. macclellandi*. They are larger and arranged differently from those of *B. japonicus* larvae. In the region of the anterior parts of dorsal and anal fins are 5 or 6 longitudinal rows. Under the posterior part of the dorsal fin and on caudal peduncle are 7 or 9 such rows. Others are present on nape, cheeks, lips, breast, belly and fleshy base of pectoral. Unpaired fins heavily pigmented, especially the posterior parts of dorsal and anal and caudal base. Fin pigmentation consists of series of elongate melanophores distributed along the fin rays. They are packed closely together and partly cover membranes of posterior parts of dorsal and anal fins. Larvae of this species are shorter and greater in cross-section than larval *B. japonicus* of similar size and development.

BREGMACEROS JAPONICUS Tanaka.

Bregmaceros atlanticus japonicus Tanaka 1908, p. 42, fig. — (Sagami Sea, Japan—Type locality). Parr 1931, p. 49.

Bregmaceros japonicus Tanaka 1913, p. 190, pl. 51, fig. 197 (Sagami Sea, Toyama Bay, Kagoshima). Jordan, Tanaka and Snyder 1913, p. 406. Tanaka 1933, p. 332 and fig. —. Okada 1938, p. 270.

D. (15-17) + 20 + (20-23), (55-60). A. (23-32) + (2-6) + (23-24), (52-58). Lat. sc. 72-75. Trans. sc. 13-14. Depth 8.5 to 8.6, head 6.8 to 6.9 in body length without caudal. Eye 3.3 to 5.0 in head, less than interorbital and snout. Maxilla extends to posterior border of pupil, 2.3 in head. Nuchal appendage 0.6 longer than head. Dorsal fin inserted directly above anal fin. Longest anal ray 0.5 longer than head. Ventrals 0.6 of body length without caudal, extending almost to end of low part of anal fin. Pectorals equal to distance from centre of pupil to posterior end of head. Body dusky ; back very dark. Dorsal, caudal and pectoral fins dark. Ventral and anal fins dusky. Inner lining of operculum black. (Compiled).

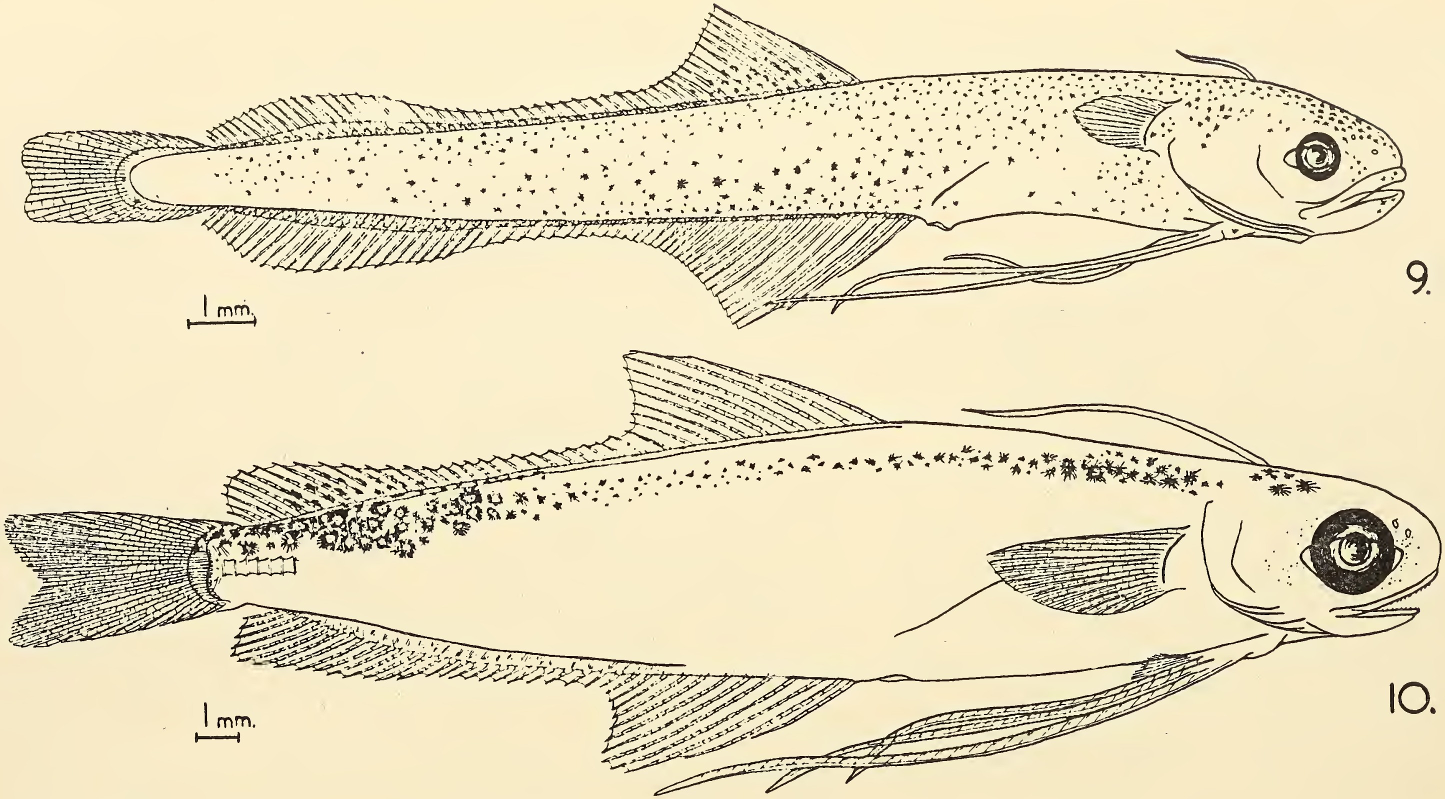
Hitherto known only from Japan. Although adults are unknown from Australian seas, planktonic larvae have been obtained by F.R.V. " Warreen " from off the coast of New South Wales (Coff's Harbour, Crescent Head and Port Hacking). The species is known also from northern New Guinea on the basis of a 25.0 millimetre specimen from Madang Harbour, collected by M.V. " Fairwind " (26.10.49) using a submarine lamp. Considered by some to be a form of *B. atlanticus*.

Larval stages.—There are 3 post-larvae which differ from those of *B. macclellandi* in pigmentation and proportions. Their elongate bodies and more numerous fin rays identify them as *B. japonicus*.

Specimens	Station	Position	Date	Net	Depth
11.5 mm.	50/38	28° 37′ S. 153° 54′ E.	22.9.38	N200	0 m.
21.0 mm.	104/38	34° 3′ 30″ S.15 1° 39′ E.	15.12.38	N200	0 m.
22.4 mm.	203/39	Off Crescent Head	18.7.39	N100	0-200 m.

11.5 *millimetre post-larva*.—(Fig. 8). Development is slightly less advanced than in the largest post-larva of *B. macclellandi*, from which it differs in having a more elongate body, greater numbers of dorsal and anal fin rays, and a pigmentation of smaller and more numerous melanophores. Head 5.5, depth 7.5 in body length without caudal. Eye equal to snout, 4.0 in head. Dorsal fin inserted slightly behind anal. Caudal fin rounded, whereas larval *B. macclellandi* of equal length has emarginate fin as in adult. Ventrals less than 3.0 in body length without caudal. D. 52-53. A. 17 + 12 + 28, (57). Numerous small stellate melanophores are scattered over the entire body and comprise 8 to 10 irregular horizontal rows. Visceral region is unpigmented except for a mid-ventral series of melanophores between the breast and anus. Others are present on supracephalic sinus, snout, preoperculum and mandible. Unpaired fins hyaline except for a few small melanophores on the basal parts of the posterior rays of dorsal and anal, and a few scattered on the caudal rays.

21.0 *to* 22.4 *millimetre post-larvae*.—(Fig. 9). Form and proportions are similar to adults of *B. japonicus*. Head 5.6, depth 7.0 to 9.0 in body length without caudal. Eye 1.0 to 1.5 in snout and interorbital, 5.0 in head, black and equipped with an adipose lid. D. 14 + 16 + 23, (53). A. 20 + 11 + 25, (56). Dorsal fin inserted noticeably behind anal origin. Ventrals extend 0.36 to 0.5 of the body length without the caudal. Pectorals 2.5 in head, with 16 to 17 rays. Maxilla reaches almost to hind border of eye. Nuchal appendage short but may be broken. Body pigmented with numerous, small, stellate melanophores



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TEXT FIGS. 9 AND 10.—Fig. 9: *Bregmaceros japonicus* Tanaka, 21.0 millimetre postlarva from "Warreen" station 104/38 (off Sydney Harbour). Fig. 10: *Bregmaceros varisquamosus* sp. nov., 33.3 millimetre female from Bostrem Bay, Sek Harbour, North Coast of New Guinea. Scale tracts not shown.

scattered irregularly over most of head and trunk. Cheeks and posterior part of visceral region unpigmented. Interorbital region with a prominent cluster of melanophores. A few small melanophores present on lips and fleshy bases of pectoral and ventral fins. Dorsal, anal and caudal fins hyaline, distinct from the heavily pigmented unpaired fins of *B. macclellandi*. At most, a few melanophores on the basal parts of the anterior dorsal rays. The 25.0 mm. post-larva from Madang has D. 17 + 20 + 22, (59) and A. 22 + 12 + 25, (59). There are 75 lateral and 14 transverse scale rows and the pigmentation is similar to that of Australian specimens.

BREGMACEROS BATHYMASTER Jordan and Bollman.

Bregmaceros bathymaster Jordan and Bollman 1889, p. 173 (Gulf of Panama—Type locality).

Bregmaceros longipes Garman 1899, p. 191, pl. 43, figs. 6-9 (Mexico, Pacific coast near Acapulco). Parr 1931, p. 49.

Bregmaceros macclellandi (*non* Thompson) Jordan and Evermann 1896-1900, p. 2526.

D. 18 + 10 + 19, (44-47). A. 19 + 10 + 19, (44-48). Lat. sc. 60-62. Trans. sc. 10. Depth 6.6 to 7.0, head 5.0 to 5.6 in body length without caudal. Eye large, 3.0 in head, greater than interorbital and approximately twice snout. Maxilla extends to or beyond middle of eye, 2.2 in head. Nuchal appendage 0.3 longer than head. Dorsal fin inserted slightly in advance of anal fin ; longest ray 0.75 of head length. Ventrals 0.66 of body length without caudal, extending to end of first section of anal fin. Pectorals shorter than head. Nape and back brown. Several rows of dark dots along front part of back and near base of anal fin. Flanks, cheeks and iris silvery. Dorsal fin dusky. Caudal fin pale, dusky at base with narrow white cross bar. Other fins pale. (Compiled).

Restricted to the Pacific coast of Central America.

BREGMACEROS ATLANTICUS Goode and Bean.

Bregmaceros atlanticus Goode and Bean 1886, p. 165 (West Indies, off Grenada and Nevis—Type locality ; Gulf of Mexico). Goode and Bean 1895, p. 389, pl. 95. Jordan and Evermann 1896-1900, p. 2527. Borodin 1928, p. 13 (Caribbean Sea, off Rancador Reefs). Parr 1931, p. 49. Parr 1937, p. 62 (West Indies, off Cuba and Bahamas).

Bregmaceros macclellandi (*non* Thompson) ? Norman 1930, p. 339 (Western Africa off Cape Lopez and Sierra Leone). ? Norman 1935, p. 9 (Angola, off St. Paul de Loanda). ? Fowler 1936, pp. 1254, 1355.

D. (15-16) + x + 16, (48). A. (15-16) + (7-8) + (21-22), (43-50) or 20 + 9 + 37, (64). Lat. sc. 65. Trans. sc. 10. Depth 7.6 to 8.0, head 5.0 to 5.75 in body length without caudal. Eye moderate, 3.5 to 4.0 in head, 1.3 to 1.5 in interorbital, equal to or slightly less than snout. Maxilla extends to below posterior edge of eye, 2.0 in head. Dorsal fin inserted directly above anal fin ; longest ray 0.2 greater than head. Ventrals 0.6 of body length without caudal, extending to end of first section of anal fin. Pectorals shorter than head. Nuchal appendage 0.5 greater than head, but according to Borodin (1928) twice body length in young. Body uniformly dusky. Young with many small, dusky stellate melanophores scattered over body. (Compiled).

An Atlantic Ocean species from Western Indies, Caribbean Sea and probably the west coast of Africa.

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ADDITIONS TO THE FLORA OF ARNHEM LAND

By C. T. White, Government Botanist, Brisbane.

(*Received 28th October,* 1949 ; *read before the Royal Society of Queensland, 28th November,* 1949 ; *issued separately* ——).

I recently had the pleasure of examining the rich ethno-botanical collections made in Arnhem Land, Northern Territory of Australia, by Dr. Donald F. Thomson in 1935-6-7 and in 1941-2-3. The specimens are preserved in museum jars in the Department of Anthropology at the University of Melbourne, and in many cases in addition as dried specimens. In making the determinations I found several species which, so far as I know, had not previously been collected in Arnhem Land or other parts of the Northern Territory and two which seem previously undescribed. A classified account of these new records is offered herewith. Types of the proposed new species have been deposited in the Queensland Herbarium.

Family Palmae

Corypha elata Roxb. Fl. Ind. ed. 2, **2** ; 176 (1832).

Arnhem Land : Glyde River, *D. F. Thomson* (photograph only) June, 1937, only seen growing on watercourses in the valley of the Glyde River, north-central Arnhem Land (palm 50-60 ft.).

This palm, a native of Bengal and Burma, is widely cultivated throughout tropical south-east Asia and the Malay Archipelago. It has been recorded from the lower Gilbert River, Cape York Peninsula, Queensland (Beccari ex Ewart and others in Proc. Roy. Soc. Vict. n.s. **24,** pt. II.: 256 (1911)) but not previously so far as I know from Arnhem Land. It is probably of Malayan introduction. The determination is based on a photograph only. It is undoubtedly a *Corypha* and I have determined it as above rather than as *C. umbraculifera* L., the Talipot palm, firstly because, as mentioned above, *C. elata* Roxb. has already been recorded for Australia and, secondly, because the photograph shows the spiral furrows on the stem that Blatter (Palms of British India p. 70) says at once distinguish this species from *C. umbraculifera* L.

Family Araceae

Amorphophallus galbra F. M. Bail. in Dept. Agric. Brisbane Bull. **21** (Bot. Bull. **7**) : 68 (1893); Queensl. Fl. **5** : 1696, Pl. LXXVI (1902).

North-West Arnhem Land : *D. F. Thomson* 49, in dry jungle associations which occur sporadically in suitable pockets near water and among hills (aroid, approx. 2 ft. high ; fruit orange and bright red in colour ; very astringent and regarded by natives as poisonous).

Typhonium angustilobum F. Muell. Fragm. Phytogr. Austr. **10** : 66 (1876).

North-Central Arnhem Land, near Cape Stewart : *D. F. Thomson* 39 *bis*, savannah forest, preferably in fairly damp locations (aroid, 6-12 in. high ; rootstock eaten by the natives).

This was included in the same jar (*No.* 39) as the more widely spread and better known *T. Brownii* Schott. of which, when better known, it may prove to be only a form or variety.

Family ZINGIBERACEAE

Curcuma australasica Hook. Bot. Mag. t. 5620 (1867).

Arnhem Land : *D. F. Thomson* 12, jungle associations generally near water and in sandy soil (flowers during wet season about January, colour of flower, tinged purplish).

Family LEGUMINOSAE

Tephrosia arnhemica sp. nov.

Herba perennis, caulibus paucis humifusis debilibus ca. 0.5 m. longis simplicibus vel pauciramosis tenuiter pubescentibus. Folia petiolata, 19-21-foliolata, rachi cum 1-1.5 cm. petiolo 5-8 cm. longa ; foliola linearia vel lineari-lanceolata, subtus tenuiter pubescentia, apice apiculata, basi leviter cuneata, breviter petiolulata, nervis praecipuis ca. 5. Racemi gracillimi, elongati, remotiflori, ad. 18 cm. longi ; flores pedicellati, pedicellis 2-3 mm. longis, dense strigoso-pubescentibus ; calyx 2 mm. longus, dense albido-pubescens, lobis acutis ; vexillum extus dense albido-hirsutum, unguiculatum, 7 mm. longum et 5 mm. latum ; alae glabrae 5 mm. longae et 2 mm. latae ; carina aequilonga ; ovarium albido-hirsutum. Legumen (immaturum) rectum 3.3 cm. longum, dense albido-hirsutum.

North Arnhem Land : *D. F. Thomson* 15, open savannah especially in sandy soil (herb, 12 in. high ; flowers small, pink or purplish in colour ; rootstock about the size of a small parsnip, used to poison fish).

Very close to *T. remotiflora* F. Muell. ex Benth., but the two can be distinguished as follows :

Upright shrub or subshrub, leaflets 7-11, oblong-cuneate, lateral veins numerous and close together .... *T. remotiflora*

Herb or subshrub, several weak diffuse stems from a common stock, leaflets 19-21, linear or linear lanceolate, lateral nerves distant about 5 on each side of the midrib .... *T. arnhemica*

Family ANACARDIACEAE

Buchanania arborescens Blume Mus. Bot. Lugd. Bat. **1** : 183 (1850).

North-East Arnhem Land : *D. F. Thomson* 113, chiefly in higher rainfall areas where the vegetation has a rain-forest appearance (tree 15-20 ft.).

Distribution : Burma, Malay Archipelago, Philippine Islands and tropical Australia.

Buchanania obovata Engler in DC. Monogr. Phan. **4** : 187 (1883).

Far-eastern Arnhem Land : South of Melville Bay and vicinity of Port Bradshaw ; *D. F. Thomson* 2, 20 and 81.

Distribution : Confined to Australia.

There has been considerable confusion regarding the species of *Buchanania* in Australia. *B. arborescens* Bl. as I understand the species is common in Queensland. According to Dr. Thomson, in Arnhem Land it grows in the jungle (monsoon forest or light rain-forest) whereas *B. obovata* Engl. is a savannah-forest tree. It is rare in Queensland.

Family SAPINDACEAE

Ganophyllum falcatum Blume Mus. Bot. Lugd. Bat. 1: 230 (1850).

Arnhem Land: North coast, *D. F. Thomson* 4, on raised area above sand beach on fringe of dry jungle (tree 30-35 feet, fruit reddish orange, matures in December, eaten by natives).

Distribution: Andaman Islands, Philippines, Java, New Guinea and tropical Australia.

Family COMBRETACEAE

Terminalia carpentariae sp. nov.

Arbor 10-13 m. alta, ramulis densissime velutino-pubescentibus. Folia subchartacea oblonga vel rarius elliptico-oblonga plerumque obtusissima et interdum leviter emarginata, rarissime breviter acuminata, basi obtusa vel rarissime brevissime cuneata, utrinque dense et molliter pubescentia, nervis praecipuis ca. 7 in utroque latere, reticulatione utrinque prominulo vel subtus interdum plus vel minus prominenti; petiolus 2-4 cm. longus; lamina 8-12 cm. longa, 6-9 cm. lata. Spicae fructiferae 6-8 cm. longae, densissime velutino-pubescentes. Drupae dense velutino-tomentosae, 3 cm. longae, 1.7 cm. latae, 1 cm. diam., ellipsoideae, rostratae compressae vel plano-convexae, lateribus acute angulatis.

NORTHERN TERRITORY: Arnhem Land: north coast, Crocodile Islands, *D. F. Thomson* 111 (TYPE), chiefly in zone fringing the sea-front (tree 30-40 feet, cambium layer used for caulking canoes). Settlement Creek, *L. J. Brass* 236, October, 1922, hill country (small tree, fruit said to be excellent eating when stewed. Local name " Plum Tree ").

QUEENSLAND: Burke District: Gulf of Carpentaria, Mornington Island: *J. F. Bailey*, June 1901; *E. W. Bick* 236, October, 1922; Lawn Hill: *H. I. Jensen* 94, May, 1940.

This tree grows in several parts of the " Gulf " country of Queensland and is apparently common and widely spread in the Northern Territory, as in addition to the specimens quoted above it is represented by several sheets in the Blake (Northern Australia Regional Survey) and Specht (Australian-American Arnhem Land Expedition) collections. It is undoubtedly very closely allied to *T. platyphylla* F. Muell., with which it has been confused in the past. Another very closely allied species is *T. aridicola* Domin.

The Australian species of *Terminalia* are notoriously difficult to delimit, but I think we are dealing with three distinct species here which can be keyed out or rather summarised as follows:

Leaves mostly cuneate, rarely subobtuse at the base, more or less densely pubescent on both surfaces, petiole 1-2 cm. long, lamina 4-8 cm. long, 2-5 cm. wide, lateral nerves about 6 on each side of the midrib; drupe broadly and shortly ellipsoid, not rostrate, not compressed but with sharp angles almost developed into lateral wings in the younger stage, disappearing and only remaining as a sharp edge in the mature fruit, densely pubescent, 2.5 × 2 × 1.5 cm. .... *T. aridicola*

Leaves mostly cuneate, very rarely obtuse at the base, glabrescent above or at most thinly pubescent, petiole 2-3 cm. long, lamina 10-17 cm. long, 6-10 cm. wide, lateral nerves 8-10 on each side of the midrib; drupe rostrate, narrowly ellipsoid without any angles or wings, not compressed nor inclined to be plano-convex, thinly pubescent, 3 × 1 × 1 cm......................... *T. platyphylla*

Leaves mostly obtuse, very rarely indistinctly and very shortly cuneate at the base, densely velvety pubescent on both faces, petiole 2-4 cm. long, lamina 8-12 cm. long, 6-9 cm. wide, lateral nerves 7 on each side of the midrib ; drupes rostrate, ellipsoid, more or less compressed or plano-convex (or at least very slightly convex on one face and markedly so on the other), acutely angled on the sides, densely tomentose, 3 × 1.7 × 1 cm. .... *T. carpentariae*

Family THYMELAEACEAE

Phaleria blumei Benth. var. **latifolia** Benth. Fl. Austr. **6** : 38 (1873).

Arnhem Land : Caledon Bay, *D. F. Thomson* 57, August 1936, near the beach (shrub, used as a fibre plant).

Distribution : Malay Archipelago, tropical Australia.

Family RHIZOPHORACEAE

Bruguiera parviflora (Roxb.) Wight & Arn. Prodr. 311 (1834).

North Arnhem Land : Crocodile Islands, *D. F. Thomson* 28, September 1935, mangrove zone (tree 20-25 feet, wood used by natives for canoe paddles).

Distribution : India, Malay Archipelago, tropical Australia.

HEAVY MINERAL BEACH SANDS OF SOUTHERN QUEENSLAND.—Part II.

PHYSICAL AND MINERALOGICAL COMPOSITION, MINERAL DESCRIPTIONS, AND ORIGIN OF THE HEAVY MINERALS.

BY A. W. BEASLEY, M.SC., PH.D., D.I.C., F.G.S., c/- Department of Geology, University of Queensland.

(WITH FIVE TEXT-FIGURES AND SIX PLATES.)

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CONTENTS.

SUMMARY.

The physical and mineralogical composition of 50 samples of heavy mineral sands, collected from along a 300-mile stretch of the Eastern Australian coast, are described. Results of sieve analyses of the samples of natural concentrate, and of the panned heavy mineral concentrate obtained from them, are presented. The median diameter, coefficients of sorting and log skewness of the heavy mineral concentrates are given, and the values plotted against distance of the samples along the coast from south to north. Descriptions and comparisons of physical compositions are based mainly on these measures, and they are shown to be of use in suggesting places of heavy mineral addition and direction of transport along the coast. The percentage of heavy minerals in the natural concentrates ranges up to 95.2% by weight. Mineral analyses of the heavy mineral concentrates are given in weight percentages, and 20 species are listed. The minerals are described and the geographic distribution along the coast is discussed. Over 90% of the heavy minerals in all the samples consist of zircon, rutile and ilmenite. Decreases in the degree of zircon abrasion around the major coastline breaks and about the headlands of Mesozoic sandstone suggest that heavy mineral material has been added to the shore at these points. The geology of the region, and study of the heavy mineral assemblages of 20 selected rock samples and 11 river sand samples indicate that Mesozoic freshwater sandstones are the immediate source rock for most of the heavy minerals in the beach sands. The main primary sources are Permian granitic

rocks, but some of the ilmenite in the sands has been derived from Tertiary basalts. An outline of the geological history of the heavy minerals is presented.

I. INTRODUCTION.

From 1945 to 1947 an investigation was carried out into the nature, distribution, extent, and manner of formation of the heavy mineral sand deposits of the S.E. Queensland coast. The results of this have already appeared in these Proceedings (Beasley, 1948).

During the field work samples were collected from places of heavy mineral concentration on the beaches and the adjacent dunes. These, together with a number collected by the Queensland Geological Survey, form the material on which the present work is based. The samples were obtained from the 250-mile stretch of Queensland coastline between the New South Wales border in the south and Indian Head on Fraser Island in the north. A small representative collection was obtained from Northern New South Wales for comparison with the Queensland sands. These were collected along the coast from the State border southwards for 50 miles to Ballina.

The black sand deposits of commercial importance in Eastern Australia occur between Ballina and Moreton Island. From Moreton Island northwards to Fraser Island the deposits are small and widely separated.

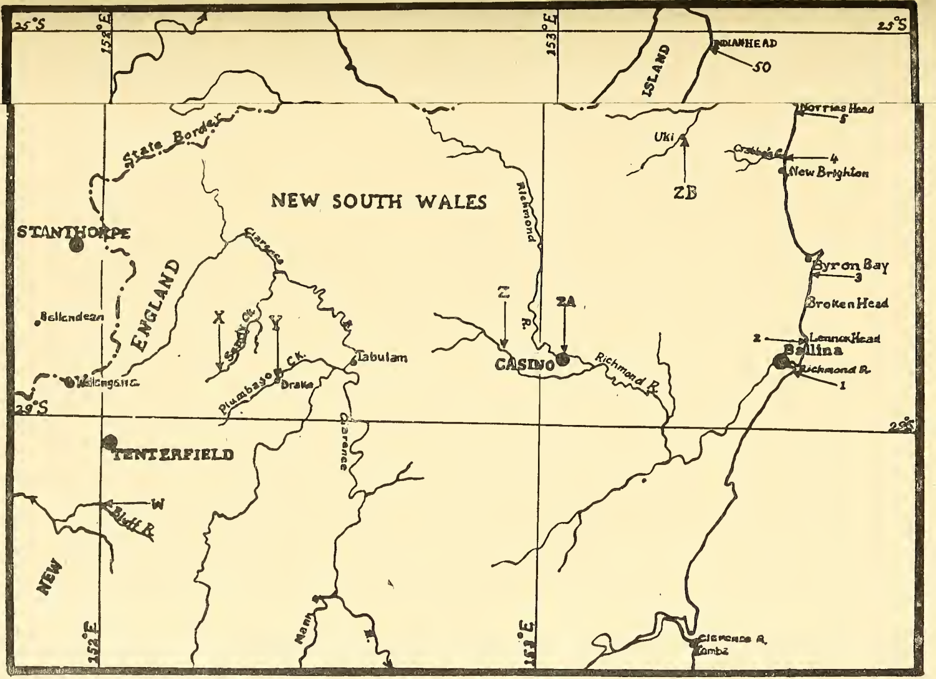
Almost all sand samples were obtained by boring with a 4-inch post-hole digger. Samples of black sand seams and composite samples of entire bores were taken as previously described (Beasley, 1948, p. 118). A small number of samples was obtained from cased bores put down with hand and power-driven plants, and a few were obtained from the faces exposed in the workings of operating companies.

The main objects of the present work have been to determine the physical and mineralogical constitution of the sands, particularly the heavy mineral content, to describe the heavy minerals, and to enquire into their origin. For economic reasons, weight percentages of the heavy mineral species have been determined in preference to mineral grain number percentages.

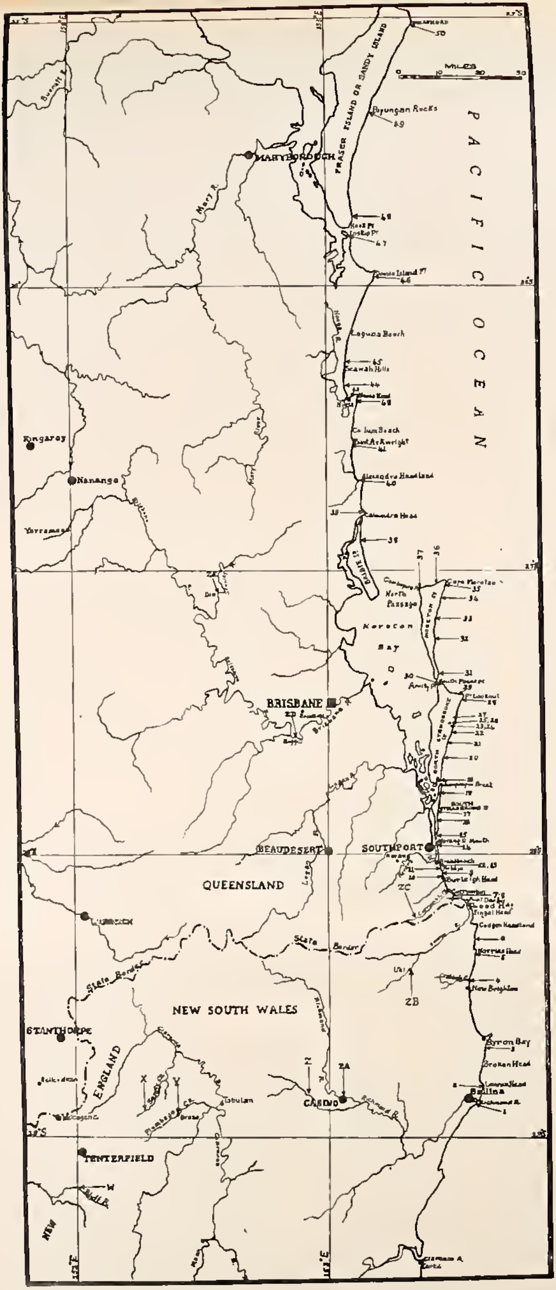
II. PLACES OF COLLECTION OF THE BEACH SAND SAMPLES.

The localities given are numbered consecutively from south to north. Unless otherwise stated, the samples are from black sand seams in bores. The first six samples are from Northern New South Wales.

1. Top of beach just S. of mouth of Richmond River, Ballina.
2. Immediately in front of foredune on S. side of Lennox Head.
3. Seam exposed in workings on Seven-Mile Beach, just S. of Byron Bay.
4. Seam exposed in beach workings near mouth of Crabbe's Creek, 4 miles N. of New Brighton.
5. Behind foredune, ¼ mile S. of Norries Head.
6. Top of beach, 3 miles S. of Cudgen Headland.
7. Top of beach 4 chains N. of Tugun Surf Pavilion.
8. Seam exposed in beach workings at Flat Rock, Tugun.
9. Seam exposed in beach workings ½ mile S. of South Nobby Headland and opposite Fifth Avenue, Burleigh.
10. Composite sample of 6 feet in bore in most landward of Recent coastal dunes, ¼ mile inland, at South Nobby.
11. Immediately behind third dune ridge inland from beach, ½ mile N. of North Nobby.



TEXT-FIGURE I.— LOCALITY MAP, SHOWING PLACES OF COLLECTION OF SAND SAMPLES.



TEXT-FIGURE I.— LOCALITY MAP, SHOWING PLACES OF COLLECTION OF SAND SAMPLES.

12. Hollow between two dune ridges ¼ mile inland, 1 mile S. of Broadbeach Surf Pavilion.
13. Seam exposed in workings immediately behind foredune, ¼ mile S. of Broadbeach Surf Pavilion.
14. Immediately in front of foredune, on Southport sandspit, 2 miles S. of Nerang River mouth.
15. Seam exposed in vertical wave-eroded scarp at top of beach, ½ mile N. of southern extremity of South Stradbroke Island.
16. Composite sample of 3 ft. bore containing thin black sand seams, immediately in front of foredune, 3¼ miles N. of southern extremity of South Stradbroke Island.
17. Top of beach, 5 miles N. of southern extremity of South Stradbroke Island.
18. Seam exposed in deep hollow immediately in front of foredune, 8½ miles N. of southern extremity of South Stradbroke Island.
19. Top of beach near extreme southern end of North Stradbroke Island, just N. of Jumpinpin Break.
20. Foot of foredune, 15 miles S. of Pt. Lookout, North Stradbroke Island.
21. Foot of foredune, 12 miles S. of Pt. Lookout, North Stradbroke Island.
22. Seam exposed in deep hollow or "blow-out" in foredune, 9½ miles S. of Pt. Lookout, North Stradbroke Island.
23. Composite sample of 10 ft. bore sunk through wind-concentrated heavy mineral sand, just seaward of crest of Pleistocene foredune, ½ mile S. of mouth of Blue Lake Creek, North Stradbroke Island.
24. Composite sample of 18 ft. bore sunk through wind-concentrated heavy mineral sand, in high Pleistocene dunes 1 mile inland from present strandline and ¼ mile S. of Blue Lake Creek, North Stradbroke Island.
25. Composite sample of 18 ft. bore sunk through wind-concentrated heavy mineral sand near Blue Lake, in region of Pleistocene dunes, 1¼ miles inland from present strandline.
26. Composite sample of 36 ft. bore in Eighteen Mile Swamp adjacent to western margin, ¼ mile N. of Blue Lake Creek, North Stradbroke Island.
27. Composite sample of 18 ft. bore sunk through wind-concentrated heavy mineral sand, at elevation of 280 feet, near crest of Pleistocene foredune, 1½ miles N. of Blue Lake Creek, North Stradbroke Island.
28. Top of beach, ¼ mile S. of Pt. Lookout, North Stradbroke Island.
29. Top of beach, 1 mile E. of Rocky Point, on northern side of Stradbroke Island, just W. of Pt. Lookout.
30. Surface accumulation of black sand on beach at Amity Point Wharf, Stradbroke Island.
31. Top of beach, 1½ miles N. of southern end of Moreton Island.
32. Top of beach, 10 miles N. of southern end of Moreton Island.
33. Top of beach, 14 miles N. of southern end of Moreton Island.
34. Top of beach, 4½ miles S. of Cape Moreton, Moreton Island.
35. Top of beach, 1½ miles S. of Cape Moreton, Moreton Island.
36. Top of beach, 1½ miles W. of North Pt., near Yellow Patch, Moreton Island.
37. Top of beach, 1 mile E. of Comboyuro Pt., Moreton Island.
38. Immediately in front of foredune, 3 miles S. of northern end of Bribie Island.
39. Black sand surface accumulation on beach adjacent to Caloundra Head.
40. Black sand surface accumulation at top of beach near Alexandra Headland.
41. Immediately in front of foredune, ¼ mile S. of Pt. Arkwright.
42. Immediately in front of foredune, 1 mile S. of Paradise Caves, Noosa, along Coolum Beach.
43. Black sand surface accumulation on beach, 10 chains S. of mouth of Noosa River.
44. In front of foredune, 3 miles N. of mouth of Noosa River, along Laguna Beach
45. On Laguna Beach, 10 miles N. of Noosa.
46. Immediately in front of foredune, ¾ mile S. of Double Island Point.
47. Black sand surface accumulation on beach, 1¼ miles S. of Inskip Point.
48. Black sand surface accumulation on beach, 1 mile N. of Hook Point, Fraser Island.
49. Black sand surface accumulation on beach, immediately S. of Poyungan Rocks (recently cemented beach sand).
50. Immediately in front of foredune, 1 mile S. of Indian Head, Fraser Island.

The localities are shown in Text-figure 1.

III. MECHANICAL COMPOSITION OF THE NATURAL AND PANNED HEAVY MINERAL BEACH SAND CONCENTRATES.

Mechanical analysis of the samples of natural concentrate was carried out to obtain knowledge of their size distribution. As the grains generally have diameters greater than 0.062 mm. (1/16 mm.), it was possible to separate them into fractions with sieves.

Sieve analysis of samples of the heavy mineral concentrate obtained from the natural concentrate by panning also was carried out. Knowledge of the size distribution, sorting, and skewness of these samples was considered desirable for purposes of comparison. Satisfactory comparisons could not be made from the mechanical analysis of the natural concentrate owing to the marked difference in specific gravity between the light and heavy minerals and the local variations in the degree of natural, heavy mineral concentration. However, as in all the samples of panned concentrate over 90% of the minerals was found to consist of zircon, rutile and ilmenite, which have similar specific gravities and have been naturally concentrated in grains of very similar size, it has been possible to compare and describe these concentrates using statistical measures derived from the cumulative frequency curves. An interpretation of the mechanical analyses in terms of heavy mineral supply and transportation along the coast has thus been possible.

From Ballina to Indian Head the ocean coastline consists of a series of arc-shaped sandy beaches separated by rocky headlands. These coastline curves are broken in places by river mouths and breaks between the coastal islands, and between the islands and the mainland. The beaches are gently sloping, ranging in width up to 200 feet at low tide, and are bordered by a belt of coastal dunes. A detailed account of the physiography has been given elsewhere (Beasley, 1948, pp. 111-116). In the southern half of the area the headlands are chiefly composed of Lower Palaeozoic slates and greywackes and Tertiary basalts ; but from Cape Moreton northwards they are largely of Mesozoic sandstones, except for Indian Head, which is composed of Tertiary basalt. Throughout and beyond the area, the prevalent wind is the South-East Trade, and close to the land there is an inshore ocean current setting in a northerly direction with a rate of from a quarter to one knot. In the summer months south-east gales are not infrequent and, with the powerful waves striking the beach obliquely, the sand is drifted along the beach. Under these influences, combined with the longshore ocean current, it would seem that the direction of sand transport is mostly northward.

Mechanical Analysis.

In the laboratory, the samples of natural concentrate, usually of the order of several hundred grams, were washed free of salt, dried, and split by a rotary sample-splitter to approximately 40 grams. The sample-splitter consisted of a turntable with a tin mounted on it containing a number of glass tubes, into which the sand was discharged from an overhead funnel. The split samples were weighed, then shaken in a nest of sieves with a Ro-tap mechanical shaker for 30 minutes. The sieves used were numbers 60, 85, 100, 120, 150 and 200 of the British Standard Series, the apertures respectively being 0.251, 0.178, 0.152, 0.124, 0.104 and 0.076 mm. Distortion of the mesh due to wear was negligible. The resulting size fractions were then weighed, percentages calculated, and the results tabulated (Table I).

TABLE I.—MECHANICAL ANALYSES OF THE CONCENTRATES. AND WEIGHT PERCENTAGE OF HEAVY MINERALS IN THE SAMPLES OF NATURAL CONCENTRATE.

(The abbreviations " Nat." and " Pan." immediately after the sample numbers in the following Table refer respectively to the natural concentrate and the panned concentrate derived from it. In a few cases the panned concentrate only was sieved.)

No.	Size of openings in millimetres							wt. % h. mins.
	>.251	.251—.178	.178—.152	.152—.124	.124—.104	.104—.076	<.076	
	%	%	%	%	%	%	%	
1 Nat. ...	12.3	39.7	19.6	9.0	14.1	5.2	0.1	38.0
1 Pan. ...	0.1	2.2	5.2	9.5	72.0	3.0	8.0	
2 Nat. ...	4.3	20.6	10.1	4.9	45.3	8.2	6.6	61.6
2 Pan. ...		2.7	6.1	9.2	66.2	9.2	6.6	
3 Nat. ...	13.6	46.2	18.1	5.4	11.1	3.6	2.0	28.5
3 Pan. ...		2.0	4.9	6.2	63.2	4.5	19.2	
4 Nat. ...	1.4	6.1	6.5	5.8	65.1	8.0	7.1	90.4
4 Pan. ...		2.3	5.3	9.4	72.2	2.4	8.4	
5 Pan. ...		2.7	5.9	6.9	68.7	13.2	2.6	
6 Nat. ...	4.6	15.4	8.1	6.9	56.5	2.6	5.9	77.4
6 Pan. ...	0.8	5.6	6.6	7.3	69.0	5.5	5.5	
7 Nat. ...	7.6	24.7	9.1	5.1	44.4	7.7	1.4	54.9
7 Pan. ...	0.4	5.6	6.8	5.8	69.3	4.0	8.1	
8 Pan. ...		4.2	7.0	8.1	62.1	10.2	8.4	
9 Nat. ...	2.2	10.1	8.8	7.6	60.2	3.2	7.9	87.6
9 Pan. ...	0.2	2.3	3.9	6.0	70.6	3.6	13.4	
10 Nat. ...	38.1	45.8	6.6	2.4	5.0	1.6	0.5	10.1
10 Pan. ...	3.3	27.0	18.4	8.6	34.6	6.7	1.4	
11 Nat. ...	14.8	34.4	8.5	4.9	30.6	7.3	0.4	32.6
11 Pan. ...	1.0	10.1	8.9	5.6	58.4	11.2	4.8	
12 Pan. ...	0.3	4.3	4.6	4.9	57.1	23.4	5.9	
13 Nat. ...	4.3	12.5	8.8	9.6	53.7	4.9	6.2	80.2
13 Pan. ...		6.9	8.0	7.3	66.5	9.6	1.7	
14 Nat. ...	2.0	26.4	10.9	6.3	39.5	10.9	4.0	67.4
14 Pan. ...		7.1	8.6	5.9	59.6	16.8	2.0	
15 Nat. ...	14.9	49.9	8.8	4.7	17.9	0.3	3.5	40.8

TABLE I.—*continued.*

No.	Size of openings in millimetres							wt. % h. mins.
	< .251	.251—.178	.178—.152	.152—.124	.124—.104	.104—.076	< .076	
	%	%	%	%	%	%	%	
15 Pan. ...	5.0	25.6	13.5	5.6	42.0	14.1	4.2	
16 Nat. ...	22.7	46.7	7.2	3.4	14.9	3.8	1.3	21.3
16 Pan. ...	1.1	11.6	8.9	6.2	55.4	3.9	12.9	
17 Pan. ...	0.3	4.8	3.2	3.0	55.3	16.0	17.4	
18 Nat. ...	0.8	20.0	13.1	7.4	53.1	3.3	2.3	81.9
18 Pan. ...	0.1	10.6	12.7	9.4	62.1	2.7	2.4	
19 Nat. ...	7.1	42.5	13.6	7.2	28.1	1.4	0.1	47.3
19 Pan. ...	0.5	12.4	18.4	12.6	53.4	2.0	0.7	
20 Pan. ...	0.2	5.6	6.3	4.5	53.8	14.8	14.8	
21 Nat. ...	7.6	34.2	8.4	4.6	35.4	2.9	6.9	63.3
21 Pan. ...	1.2	14.8	11.1	5.4	53.3	6.7	7.5	
22 Nat. ...	0.8	29.6	10.5	6.5	48.9	2.3	1.4	86.1
22 Pan. ...		3.9	6.7	5.0	56.2	23.9	4.3	
23 Pan. ...	0.2	2.8	4.4	5.4	53.6	27.9	5.7	
24 Pan. ...	0.1	2.9	5.4	5.0	49.0	26.7	10.9	
25 Nat. ...	26.3	62.3	8.2	2.0	1.0	0.1	0.1	4.1
25 Pan. ...	0.4	5.7	6.7	5.3	47.2	23.8	10.9	
26 Pan. ...	0.5	8.0	9.2	5.8	51.7	10.9	13.9	
27 Pan. ...		1.9	3.6	3.5	54.2	29.0	7.8	
28 Nat. ...	11.0	68.3	12.7	4.2	3.4	0.2	0.2	10.2
28 Pan. ...	0.1	3.8	6.6	5.0	56.3	23.6	4.6	
29 Nat. ...	15.2	49.6	13.7	7.6	10.7	2.8	0.4	10.5
29 Pan. ...	0.6	11.2	14.5	10.3	47.2	9.8	6.4	
30 Nat. ...	3.8	30.8	20.6	9.4	28.2	6.3	0.9	62.4
30 Pan. ...	0.4	13.8	15.2	8.2	48.2	11.8	2.4	
31 Nat. ...	8.4	41.1	17.8	8.8	22.9	1.0		70.8
31 Pan. ...	1.8	24.7	23.1	16.7	32.4	0.6	0.7	
32 Nat. ...	5.6	27.2	10.3	7.3	41.5	6.9	1.2	64.0
32 Pan. ...	0.1	5.1	9.5	7.8	65.6	3.7	8.2	
33 Nat. ...	4.5	33.2	12.8	8.4	32.5	0.8	7.8	59.3

TABLE I.—*continued.*

No.	Size of openings in millimetres							wt. % h. mins.
	>.251	.251—.178	.178—.152	.152—.124	.124—.104	.104—.076	<.076	
	%	%	%	%	%	%	%	
33 Pan. ...	0.2	10.3	13.0	8.6	53.8	6.6	7.5	
34 Nat. ...	7.7	47.9	14.6	5.9	16.9	6.1	0.9	15.7
34 Pan. ...		4.2	9.1	8.9	53.8	15.8	8.2	
35 Nat. ...	3.0	21.9	17.2	9.3	43.5	4.7	0.4	88.8
35 Pan. ...	1.2	17.1	15.7	14.2	46.4	3.7	1.7	
36 Nat. ...	7.5	51.3	18.8	7.2	13.4	1.5	0.3	18.5
36 Pan. ...	0.8	15.8	16.9	11.1	48.9	3.8	2.7	
37 Nat. ...	4.7	19.6	11.9	9.8	45.7	3.8	4.5	79.6
37 Pan. ...	0.6	11.8	12.8	7.8	58.2	4.2	4.6	
38 Nat. ...	1.3	24.3	20.4	11.4	38.8	3.5	0.3	95.2
38 Pan. ...	1.3	30.4	22.8	15.1	27.9	1.7	0.8	
39 Nat. ...	40.6	38.8	15.4	4.3	0.8	0.1		64.5
39 Pan. ...	8.5	63.0	19.0	8.5	1.1			
40 Nat. ...	23.6	57.8	11.9	4.4	1.9	0.4		1.8
40 Pan. ...	0.5	9.1	10.4	9.6	40.6	18.3	11.5	
41 Nat. ...	19.5	41.5	19.0	8.2	10.5	1.3		72.9
41 Pan. ...	3.9	47.9	22.9	8.2	16.3	0.4	0.3	
42 Nat. ...	0.6	20.8	26.7	15.0	35.9	1.0		87.8
42 Pan. ...	0.1	21.3	27.3	16.4	33.8	0.2	0.9	
43 Nat ...	8.8	21.4	23.0	14.0	32.5	0.2	0.1	77.5
43 Pan. ...	0.1	13.8	22.9	15.9	45.7	1.6	0.2	
44 Nat. ...	0.6	9.7	9.9	8.2	51.3	6.3	14.0	76.4
44 Pan. ...		2.1	6.0	8.6	62.0	12.2	9.1	
45 Pan. ...	0.1	5.2	9.4	9.3	58.5	8.3	9.2	
46 Pan. ...	0.1	8.3	15.1	12.2	57.0	1.6	5.7	
47 Pan. ...	0.4	21.1	23.7	11.6	38.1	3.4	1.7	
48 Pan. ...	0.2	10.3	14.2	10.1	57.9	5.5	1.8	
49 Pan. ...		1.8	4.9	6.4	41.1	30.4	15.4	
50 Pan. ...	0.1	6.9	11.3	8.6	60.9	2.1	10.1	

To obtain heavy mineral samples from the natural concentrates for sieve analysis, panning was found to be satisfactory as the heavy minerals are abundant and over 95% of them differ markedly in specific gravity from the light minerals. The samples of natural concentrate were weighed and panned; porcelain evaporating dishes were used in the final stages instead of prospecting dishes as the heavy minerals remaining showed up more plainly against the white background. The panned

TABLE II.—FIRST AND THIRD QUARTILES, MEDIANS, COEFFICIENTS OF SORTING AND LOG SKEWNESS OF THE PANNED CONCENTRATES.

No.	Q1	M	Q3	So	Log Sk
		Millimetres			
1	.120	.115	.108	1.05	.004
2	.120	.115	.108	1.05	.004
3	.118	.112	.104	1.06	.004
4	.120	.115	.108	1.05	.004
5	.120	.113	.106	1.06	.000
6	.122	.114	.106	1.07	.000
7	.122	.114	.106	1.07	.000
8	.122	.114	.107	1.07	—.001
9	.120	.113	.106	1.06	.000
10	.190	.149	.112	1.30	.000
11	.124	.115	.107	1.08	—.001
12	.120	.111	.103	1.08	—.001
13	.122	.114	.107	1.07	—.001
14	.122	.113	.105	1.08	—.001
15	.192	.124	.111	1.31	—.080
16	.136	.115	.105	1.14	—.017
17	.120	.110	.100	1.10	.000
18	.149	.118	.110	1.16	—.036
19	.160	.120	.111	1.20	—.048
20	.147	.133	.118	1.11	.004
21	.155	.114	.108	1.20	—.055
22	.120	.111	.100	1.10	.004
23	.120	.110	.100	1.10	.000
24	.120	.110	.100	1.10	.000
25	.121	.110	.100	1.10	—.001
26	.123	.112	.104	1.09	—.005
27	.120	.110	.100	1.10	.000
28	.120	.111	.100	1.10	.004
29	.154	.117	.107	1.20	—.042
30	.160	.116	.106	1.23	—.052
31	.180	.151	.119	1.23	.009
32	.123	.115	.108	1.07	—.001
33	.148	.116	.106	1.18	—.034
34	.123	.113	.104	1.09	—.001
35	.166	.123	.111	1.22	—.046
36	.164	.122	.111	1.21	—.046
37	.153	.118	.110	1.18	—.043
38	.190	.153	.120	1.26	.005
39	.230	.200	.171	1.16	.000
40	.139	.114	.100	1.18	—.034
41	.217	.180	.151	1.20	—.008
42	.172	.150	.118	1.21	.019
43	.164	.128	.113	1.20	—.030
44	.121	.114	.106	1.07	.004
45	.124	.115	.106	1.08	.000
46	.150	.118	.110	1.17	—.038
47	.173	.140	.114	1.23	—.006
48	.151	.118	.109	1.17	—.037
49	.120	.111	.100	1.10	.004
50	.131	.117	.110	1.09	—.011

heavy mineral concentrate was then dried and weighed, and the weight percentage of heavy minerals in the sample of natural concentrate was determined (see Table I). Each sample of panned concentrate was split by the rotary sample-splitter to approximately 40 grams, and the split samples were weighed and screened as described for the natural concentrates. The resulting size fractions were weighed, percentages calculated, and the results tabulated (Table I). Cumulative frequency curves were constructed from this information, and from them the first and third quartiles and the median diameter were tabulated (Table II).

Comparison of the samples is based on the median diameter and the coefficients of sorting and log skewness, following Trask (1932). Where Q1 and Q3 are the first and third quartiles, respectively, and M the median, the coefficient of sorting is $\sqrt{Q1/Q3}$. It expresses the measure of the average quartile spread. Thus perfect sorting equals unity, and the larger the value the more poorly sorted is the sample. The coefficient of skewness, a measure of the dis-symmetry of the size distribution with respect to the median, is derived from the expression

$$\log Q1 \times \log Q3/(\log M)^2.$$

For convenience the logarithm of the skewness is used. Thus a minus value indicates that the mode or peak of the simple frequency curve is on the coarse side of the median, while a positive value indicates the opposite. The coefficients of sorting and log skewness of the panned concentrates were calculated and tabulated (Table II).

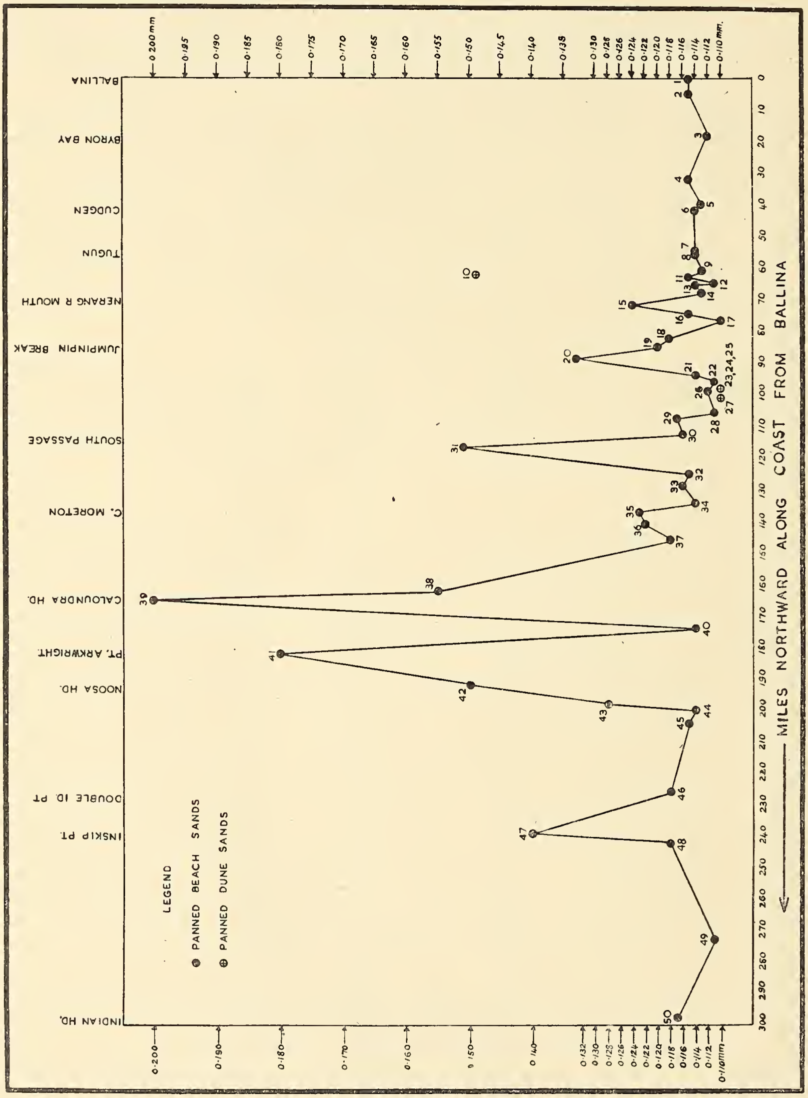
Graphical Representation and Discussion of Results.

From an examination of the mechanical analyses of the natural and panned heavy mineral concentrates shown in Table I it will be seen that the light constituents (essentially quartz) occur in coarser grains than do the heavy minerals. This may be explained by the fact that for a certain size of quartz there is a smaller size of heavy mineral which is deposited with it, because they have the same "hydraulic value" or the same settling rates. Generally, the greater the weight percentage of heavy minerals in the natural concentrate, the less the amount of material retained on the two coarsest sieves, B.S.S. Nos. 60 and 85. In all except three of the samples of panned heavy mineral concentrates, the maximum sieve-fraction percentage, which ranges from 32% in No. 31 to 72% in No. 4, lies in the 0.124 to 0.104 mm. grade size. The three exceptions are samples No. 38, 39 and 41, all of which have the maximum sieve-fraction percentage, ranging from 30.4% in No. 38 to 63% in No. 39 in the 0.251 to 0.178 mm. grade size.

In Text-figures 2, 3 and 4 the median diameter, coefficients of sorting and log skewness, respectively, of the samples of panned concentrate have been plotted against distance along the coast, from south to north.

Median Diameter.—Table II and Text-figure 2 show that the median diameter of the panned heavy mineral concentrates ranges from a minimum of 0.110 mm. (Stradbroke Island) to a maximum of 0.200 mm. (Caloundra).

From Ballina northwards to the South Passage the trend is for a slight decrease in the median values, apart from abrupt increases around the two major coastline breaks in this stretch (Nerang River mouth and Jumpinpin Break). These increases are much more pronounced on the northern side of the breaks, but on neither side are they maintained for any great distance. The general trend for a slight decrease in median values northwards in this region suggests that the material has come mainly from the south. The decrease is in the direction of the beach drift. The sudden, temporary increases around the Nerang River mouth and the Jumpinpin Break suggest that heavy mineral material is added at these points. The fact that there is much less increase on the southern side of these two major breaks appears to be due to the northward direction of sand transport. In this 106 mile-long stretch of coast the median diameter of the panned heavy mineral concentrates ranges from a minimum of 0.110 mm. to a maximum of 0.133 mm.



TEXT-FIGURE 2. — MEDIAN DIAMETER OF PANNED CONCENTRATES PLOTTED AGAINST DISTANCE ALONG COAST.

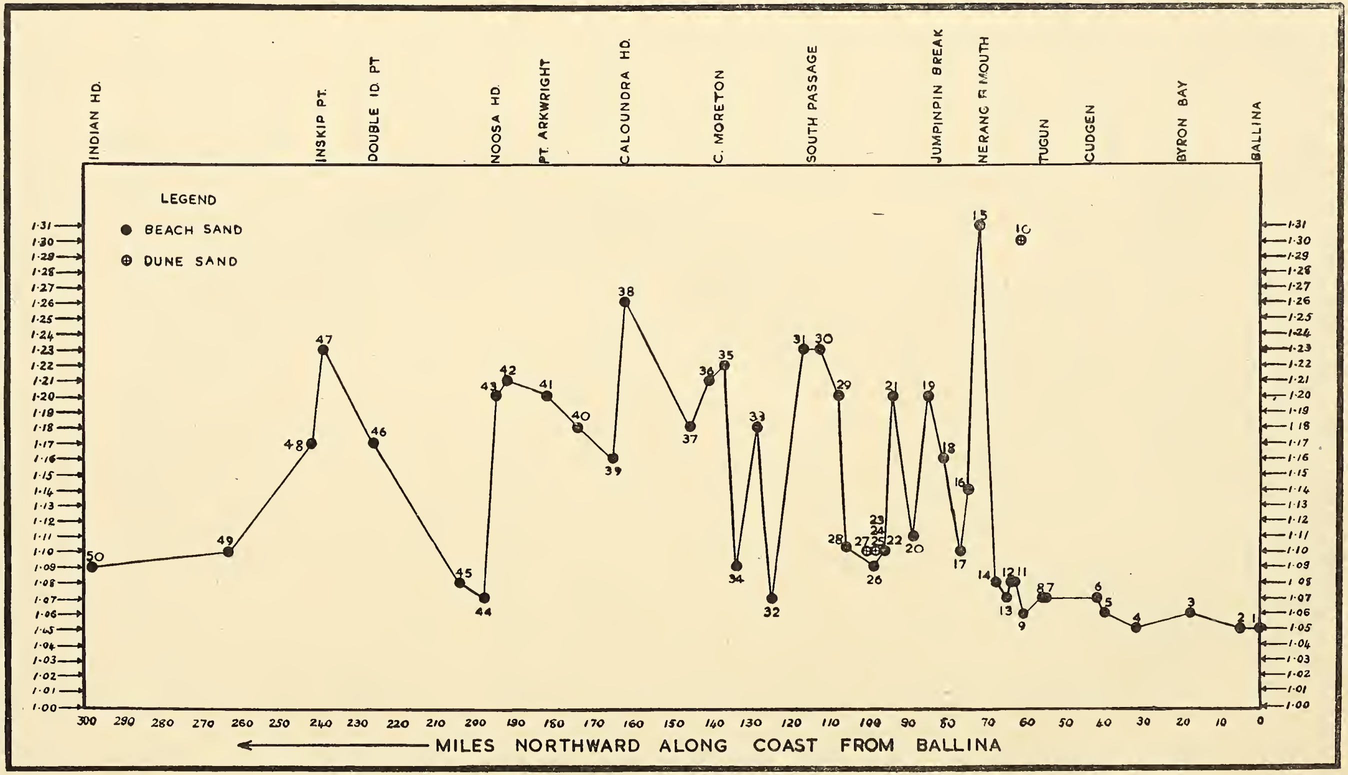
It is of interest to find that the median diameter of one of the five dune sand concentrates, sample No. 10, is as large as 0.149 mm. This may be because the heavy minerals of this sample from a low, inland dune have not been through the surf zone as often, and have not been subjected to as much abrasion by water, as those in the more recent beach sand deposits adjacent to the present strandline. Some 40 miles further north, the median diameter of the other inland dune sand concentrates, samples 23, 24, 25 and 27 is only 0.110 mm. These four concentrates, however, are from the phenomenally high dunes of North Stradbroke Island, and were collected from bores sunk at elevations ranging from 50 to 280 feet above present sea-level, and from as far as $1\frac{1}{4}$ miles inland from the present strandline. The much smaller median diameter than that of sample 10 apparently is related to the stronger winds which formed these unusually high dunes. Greater distance from the source of the heavy minerals may also be a contributing factor. All five of these concentrates are from fixed dunes in which there has been no sand-movement for many years. They have been included in this study for comparison with the 45 beach sand samples, as they are from low-grade dune sands which are at present attracting some commercial interest.

From the South Passage northwards to Indian Head the median diameter shows marked increases in samples from most of the headlands, as well as just north of two major coastline breaks (South Passage and North Passage). In this region, the headlands of Cape Moreton, Caloundra Head, Point Arkwright, Noosa Head and Double Island Point are made up largely of Mesozoic sandstones, while Indian Head is composed of Tertiary basalt. As the black sand deposits from the South Passage northwards are of small extent and are usually restricted to the vicinity of the headlands, it seems that the source of these heavy minerals with large median diameter is comparatively local in most cases. No general trend in median values is apparent for this 190 mile-long stretch of coast. From Caloundra Head northwards, however, the amount of increase in median diameter at succeeding headlands generally diminishes.

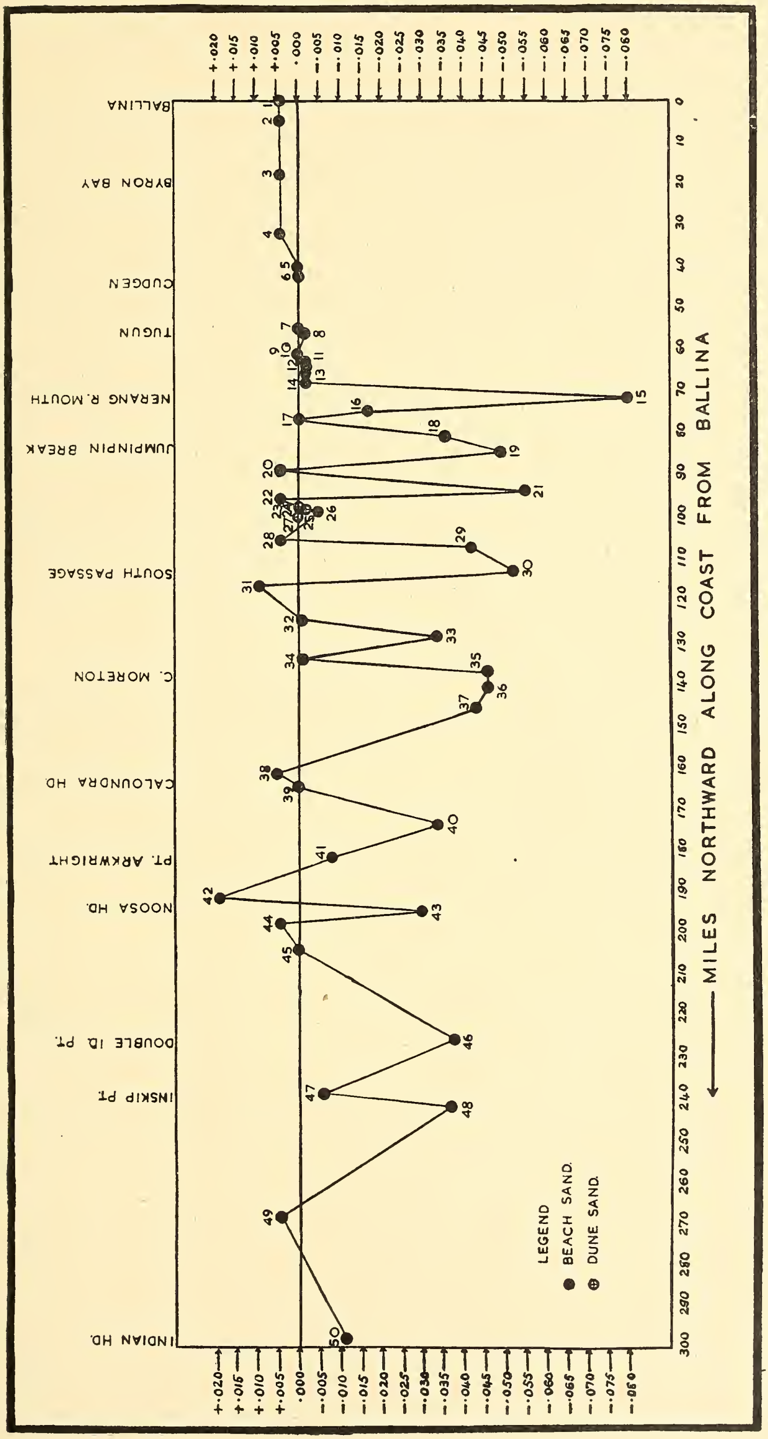
Sorting.—The heavy mineral concentrates are well sorted, the coefficient of sorting ranging from 1.05 to 1.31 (Table II and Text-figure 3). The least well-sorted heavy minerals usually occur just north of major coastline breaks and about the headlands of Mesozoic sandstone. It will be noticed too that the degree of sorting increases markedly away from these coastline breaks and sandstone headlands.

From Ballina to the mouth of the Nerang River, an area in which there are no headlands of Mesozoic sandstone and no major coastline breaks, there is a slight decrease in the degree of sorting (that is, an increase in the coefficients of sorting). This is unexpected, for throughout the area the direction of sand drift is northward under the influence of the prevailing SE. winds and northerly longshore current. Although the decrease is only a very small one, sorting was expected to increase in the direction of drift.

With reference to the five dune sand concentrates studied, sample number 10, which has a comparatively large heavy mineral median, is the least well-sorted, while samples 23, 24, 25 and 27 (those from North Stradbroke Island), which have small median diameters, are all very well sorted. However, the dune sand concentrates do not have the highest degree of sorting of the samples studied. Text-figures 2 and 3



TEXT-FIGURE 3.—COEFFICIENT OF SORTING OF PANNED CONCENTRATES PLOTTED AGAINST DISTANCE ALONG COAST.



TEXT-FIGURE 4.—LOG SKEWNESS OF PANNED CONCENTRATES PLOTTED AGAINST DISTANCE ALONG COAST.

show that poorer sorting of the individual samples is often paralleled by a large median, and greater sorting by a smaller median. That is, the sorting generally improves with increase in fineness (decrease in median diameter).

Skewness.—The values for skewness (Table II and Text-figure 4) range from —.080 (just north of the Nerang River mouth) to + .019 (at the Noosa end of Coolum Beach). The sample with the highest negative skewness is the least well-sorted of all the samples studied. Text-figure 4 indicates the very small values for skewness in the region from Ballina to the mouth of the Nerang River. Thus there are nearly symmetrical simple frequency curves for the concentrates from this stretch of coastline, with the mode very close to the median and actually corresponding with it in five samples.

From the Nerang River mouth northwards to Indian Head the mode usually is on the coarse side of the median. In this area there are only eight samples with positive values for log skewness. Four of the five dune sand concentrates examined show no skew, while the remaining one (sample 25) has a very small negative skewness of —.001. Apart from the above, no general trends are apparent in the skewness values. The fact that the mode usually is on the coarse side of the median northwards from the Nerang River mouth again suggests that the heavy minerals have been contributed more recently to the beach than those in the southern part of the region.

IV. MINERALOGICAL METHODS.

The methods adopted in determining the mineralogical composition of the sand and rock samples studied in this investigation are described below, as well as the methods of determining abrasion and grain size measurement under the microscope. River-sand and rock samples were examined in connection with the enquiry into the origin of the beach sand heavy minerals. In all cases the rotary separator already described was used for sample splitting, and bromoform of specific gravity 2.86 was employed for the initial heavy liquid separation.

Sand Samples.

A small sample of the natural concentrate, split from the bulk sample, was submitted to bromoform separation in a nearly cylindrical funnel to minimize adherence of particles to the sides. After washing with industrial methylated spirits and drying in an oven, the heavy mineral concentrate was split in size to approximately 5 grams and weighed. As it was desired to distinguish between magnetite, ilmenite, chromite, and " black " rutile grains, the highly magnetic and moderately magnetic minerals were separated from the samples with an electromagnet. A number of black and nearly black rutile grains was found in all the samples, identification being established definitely by chemical analysis of hand-picked grains. The highly magnetic fraction (magnetite) was extracted first with the electromagnet calibrated for the purpose, and its weight percentage determined. An aluminium shield was placed under the pole-pieces to make removal of the magnetite grains easier after the current was switched off. The moderately magnetic minerals (ilmenite, chromite and garnet) next were removed with the electromagnet precisely calibrated, and the weight percentage of this fraction was determined. The garnet (almandine) was separated from the ilmenite and chromite with concentrated Clerici's Solution of specific gravity 4.25 and, after washing with water and drying, the weight percentages of both the garnet and the ilmenite-chromite fractions were determined. In the case of the beach sand samples, the small amount of chromite present was separated from the ilmenite with concentrated Clerici's Solution heated to 42° C. (at which temperature its specific gravity is about midway between that of the chromite and the ilmenite), and the percentage of each of these minerals in the sample was calculated. In the river sand samples, however, the small amount of chromite, where present, was not separated from the ilmenite.

The quantity of weakly magnetic minerals was very small and they were not separated from the non-magnetic minerals in the sample. The combined weakly magnetic and non-magnetic fraction of the sample was weighed, and then divided into two size fractions by shaking in a B.S.S. No. 120 sieve (aperture size 0.124 mm.) until particles ceased to pass through the mesh. The weight percentages of the resulting size fractions were calculated, and each fraction was then split to about one to two thousand grains and mounted entirely on a glass slide. In most cases permanent mounts were made in Canada balsam, Twenhofel and Tyler's (1941, p. 168) technique being followed. Temporary mounts in eugenol (clove oil) were also made. The grains of each mineral species were then counted in some 8 to 12 different fields across different parts of the mount, the number of grains usually being of the order of 800 to 1,000. The number of grains of each mineral species was multiplied by the specific gravity of the mineral in order to obtain a figure in terms of weight. The specific gravity of the zircon, rutile, monazite and cassiterite was determined with a pycnometer as 4.68, 4.21, 5.19 and 6.90 respectively. For these determinations, small quantities of the commercial mineral concentrate, after handpicking under a binocular microscope to obtain purity, were used. The specific gravity of the tourmaline-leucoxene, epidote, spinel, corundum, hypersthene, andalusite, horn, blende, sphene, staurolite, and kyanite was taken as 3.1, 4.0, 3.4, 3.6, 4.0, 3.4, 3.1, 3.2, 3.5, 3.7, and 3.6 respectively. The percentages of the various mineral species in each of the size fractions were then calculated. These figures were each multiplied by the weight percentage of the size fraction divided by 100, and the results for like species in both size fractions were added. The percentages of these various minerals in the entire sample were then determined from multiplication by the weight percentage of the weakly and non-magnetic mineral fraction divided by 100. Because of the small spread of all the weakly-magnetic and non-magnetic minerals present, it was possible to take the grain size variation into account by division into two fractions with the B.S.S. No. 120 sieve in the determination of the weight percentages of these minerals.

Rock Samples.

In most cases the size of the samples of metamorphic, igneous and sedimentary rocks taken for breaking down was about one-quarter the size of a normal rock hand-specimen.

Metamorphic and Igneous Rocks.—The samples of metamorphic and igneous rocks were mechanically disintegrated, first by cracking in a jaw-cracker, and then by hammering in an iron mortar with closely fitting pestle, similar to that figured by Krumbein and Pettijohn (1938, p. 313). Disintegration was continued until the particles obtained were monomineralic. To avoid the formation of a large amount of fine rock-flour and total destruction of the original form of the grains, the material was sieved at intervals, the oversize being crushed until it was reduced to grains consisting of single minerals. With the plutonic rocks the sieve used to separate the composite from the monomineralic particles was B.S.S. No. 52 (aperture size 0.295 mm.), while B.S.S. No. 85 (aperture size 0.178 mm.) was used with the metamorphic and volcanic rocks. After the removal of the rock-flour by washing with distilled water and decanting, the material was dried, split to about 50 grams, and weighed. The heavy mineral particles were separated in bromoform and, after weighing, the index-figure was calculated. This is the weight percentage of mineral grains of specific gravity greater than 2.86 obtainable from the crushed rock material which has been washed free from rock-flour. The magnetic minerals were then separated with the electromagnet. Because of the variety and large bulk of magnetic minerals in the igneous rocks and the difficulty of effecting clean separations, the weight percentages of highly magnetic, moderately magnetic, and weakly magnetic mineral fractions were not determined individually. In most cases, however, a rough separation into these three magnetic groups was made as it facilitated the identification of certain of the minerals and assisted in estimating the relative abundance of the minerals in the samples. The magnetic and non-magnetic heavy mineral fractions were examined under the microscope in permanent and temporary mounts. Because of the disintegration of the rocks entirely by mechanical means, it was considered impracticable to determine the mineral percentages by any method employing grain counting. The relative abundance of the minerals, accordingly, were determined by estimation and recorded by symbols in the Milner (1929, p. 386) Scale.

Sandstones.—The sandstone samples were broken into small pieces in the jaw-cracker, and then heated to a high temperature. While hot they were dropped into a beaker of cold water, and allowed to remain in it for several days. In some cases the material thus became partly broken down, and the individual particles were freed by gentle crushing with a pestle or with the fingers. In other cases the rock was disintegrated by warming with a 20% solution of HCl. To restrict the time of acid treatment, the material was disturbed and partly broken down with a pestle at intervals during the digestion. Vigorous crushing was avoided, however, so that the grains would be as nearly as possible in the same condition as before disintegration. After the sample was completely disintegrated, the mineral particles were washed and weighed, the heavy minerals separated in bromoform, and the weight percentages determined. These correspond to the index-figure of the other rocks. Because of the small bulk of the heavy minerals obtained from each sample, it was impracticable to divide it into fractions with the electromagnet. In some cases the bulk was such that the heavy minerals were mounted entirely on a glass slide. In other cases, where the bulk was greater, part of the fraction was mounted on a glass slide and the remainder was kept unmounted for supplementary study. The grains of each mineral species were then counted in the same way as that described above for the weakly magnetic and non-magnetic fraction of the sand samples, and the weight percentages of the various minerals were determined. Unfortunately, it was impossible to distinguish with certainty between the black iron ores under the microscope. However, examination of the unmounted material showed the iron ores to be moderately magnetic. From this fact, combined with an examination of these grains by reflected light, it would appear that they are almost entirely ilmenite, although very small amounts of chromite and magnetite are sometimes present. In this work the iron ore grains were all multiplied by the specific gravity of the ilmenite concentrate, determined with a pycnometer as 4.69, and the specific gravity of each of the various other minerals was the same as that used for the sand samples. Because of the small bulk of heavy minerals, allowance was not made for the variation in size of the mineral grains in the determination of the weight percentages. However, it was observed under the microscope that the variation in size of the heavy mineral grains was not great. Accordingly, it is felt that a fairly high degree of accuracy can be assigned to the mineral weight percentages calculated from the number of grains of each mineral species and its specific gravity.

Abrasion.

For each of the sand samples and the metamorphic and sedimentary rocks a quantitative determination of abrasion was carried out by calculating the number percentage of rounded zircon grains as distinct from euhedral and subhedral grains. The total number of zircon grains examined and counted in each sample was of the order of 300. Euhedral grains are those with all visible crystal faces and edges intact, while subhedral grains are those with only some faces and edges recognizable, and rounded grains those with no faces or edges identifiable. Zircon was chosen as a standard for this quantitative abrasion work because of its great stability, its abundance in the samples, and the wide range in the degree of its abrasion due to a hardness greater than most of the other heavy minerals present.

Grain Size Measurement.

As the bulk of heavy minerals obtained from the rock samples was insufficient for sieve analysis, measurements were made with an eyepiece micrometer of the zircon grains in each of these assemblages. For this work the intermediate diameter of 100 zircon grains in each sample was determined and a mean taken in each case, following Allen (1944, p. 73). The intermediate diameter is the dimension at right angles to the long axis of the grain, as seen in a microscope slide the cover slip of which has been pressed firmly down during mounting (in which case the grains come to lie with their shortest axis vertical and their longest and intermediate axes in the plane of the slide). It is a particularly useful measure of size, since it is the same dimension as is estimated by sieving.

V. MINERALOGICAL COMPOSITION OF THE HEAVY MINERAL BEACH SAND CONCENTRATES.

The weight percentage of heavy minerals in the samples of natural concentrate ranges up to 95.2%, and in most cases it is greater than 50% (Table I). The light mineral fraction was composed almost entirely of quartz grains ; very little felspar is present.

In the accompanying Table the numbers indicate weight percentages, and the symbol " x " that the mineral is present in amounts less than 0.1%. The more common species are on the left, and the rare ones to the right. For convenience, the degree of abrasion of the sands, calculated as the number percentage of rounded zircon grains in each sample, is incorporated. The following abbreviations are used :—

TABLE III.—MINERAL ANALYSES OF HEAVY MINERAL SAMPLES IN PERCENTAGES BY WEIGHT, AND ABRASION GRAIN NUMBER PERCENTAGES.

No.	Zir	Ru	Il	Gar	Tour	Mon	Leu +	Chr	Cass	Epi	Spin	Mag	Cor	Hyp	Andal	Horn	Sph	St	Ky	Ab
1	53.4	23.0	20.1	0.4	0.5	0.7	0.4	0.9	0.1	0.2	0.2	0.1	X	X			X			66
2	55.6	20.1	21.0	0.8	0.4	0.7	0.8	0.4		X	0.1	0.1							X	78
3	52.3	23.5	20.2	0.8	0.6	0.8	0.5	0.8	0.1	0.2	0.1	X	X	X				X		64
4	50.8	22.4	23.3	0.6	0.5	0.6	0.7	0.6	X	0.4	X	0.1		X	X					74
5	51.0	23.2	21.2	1.0	0.8	0.7	0.5	0.9	0.1	0.2	0.2	0.2				X		X	X	81
6	54.6	21.5	21.2	0.4	0.2	0.6	0.9	0.4		0.1	X	0.1			X					79
7	47.4	26.3	22.5	0.9	0.5	0.8	0.8	0.5	0.2		0.1	0.1								70
8	50.2	25.5	20.9	0.3	0.3	0.7	0.4	0.9	0.4	0.2	0.1	0.1					X			78
9	48.4	25.1	22.3	1.1	0.8	0.7	0.6	0.5	0.1	0.1	0.2	X		X						73
10	31.3	20.0	44.2	0.9	1.5	0.7	0.4	0.9		X	X	0.1							X	78
11	46.2	26.5	23.9	0.8	0.7	0.5	0.4	0.7	0.2	X		0.1								74
12	46.7	28.0	21.6	0.9	0.6	0.6	0.5	0.8		0.1	0.1	0.1				X				77
13	45.4	26.8	25.1	0.5	0.4	0.7	0.4	0.7		X		X	X							78
14	40.9	27.3	26.5	0.8	1.8	0.8	1.1	0.5		0.2		X								70
15	33.4	34.5	28.2	0.8	0.9	0.3	0.9	0.8	X		0.1	0.1			X		X			69
16	34.7	31.0	30.9	0.6	0.9	0.3	0.5	0.9		X		X								61
17	29.6	32.9	33.8	0.3	0.9	0.4	1.0	0.8			0.1	X								80
18	32.5	31.8	31.4	0.6	1.6	0.4	1.1	0.4	X			0.1		X				X		68
19	32.3	35.5	28.1	1.4	0.8	0.4	0.7	0.4		0.1	0.1	X								62
20	29.0	32.4	35.0	0.4	1.5	0.6	0.5	0.3		0.2		X	X							72
21	30.2	33.3	32.8	0.6	1.6	0.2	0.8	0.3		0.1		X			X					72
22	30.4	35.7	30.1	0.5	1.3	0.2	1.1	0.4	0.1	X		0.1				X				77
23	28.0	26.1	41.2	0.4	1.8	0.2	0.9	0.4	0.1	0.4	0.2		X					X		72
24	30.1	26.2	40.4	0.2	0.6	0.3	1.2	0.3		0.4	0.1	X		X		X				72
25	36.6	22.5	38.1	0.2	1.3	0.2	0.5	0.4		X		0.1				X				74

TABLE III.—*continued.*

No.	Zir	Ru	Il	Gar	Tour	Mon	Leu +	Chr	Cass	Epi	Spin	Mag	Cor	Hyp	Andal	Horn	Sph	St	Ky	Ab
26	25.9	22.1	49.8	0.2	0.8	0.1	0.6	0.4		X		X		X	X			X		53
27	26.6	28.3	41.8	0.1	1.5	0.2	0.8	0.6				X				X		X		71
28	25.8	35.9	34.9	0.4	1.6	0.4	0.4	0.5		X		0.1	X			X				73
29	28.0	29.1	40.1	0.2	0.3	0.4	1.1	0.8		X	X	X								69
30	24.8	18.6	54 0	0.2	0.4	1.2	0.2	0.4		0.2		X								68
31	18.5	12.4	65.7	0.4	0.5	0.9	0.7	0.8		X		X					X			59
32	20.9	15.8	59.8	0.6	0.4	1.0	0.6	0.6	X			0.1		X		X				65
33	18.7	20.1	54.9	0.8	2.5	0.7	1.3	0.8		X	X	0.1					X		X	64
34	25.9	20.2	49.9	0.2	1.2	0.5	0.8	0.9	X	0.1	0.1	0.1	X							66
35	24.2	15.9	57.1	0.2	0.5	0.5	0.8	0.6	X	X		0.1								66
36	20.4	15.5	60.1	0.4	1.0	0.8	0.9	0.6		0.1		0.1								74
37	23.5	16.2	57.7	0.5	0.3	0.6	0.5	0.6	X			X								71
38	22.1	19.0	55.7	1.0	0.3	0.5	0.6	0.7		X		0.1				X				62
39	20.6	20.2	50.1	5.2	0.2	2.4	0.5	0.8		X		X								66
40	19.4	20.4	50.2	8.3	0.1	1.1	0.3	0.2		X		X					X			45
41	17.0	15.2	58.0	7.1	0.3	1.5	0.4	0.3		X	X	0.1					X			64
42	17.6	16.5	59.8	3.5	0.4	1.1	0.5	0.4			0.1	X				X				64
43	20.1	16.8	59.3	1.5	0.4	1.0	0.4	0.4	X			X				0.1				65
44	24.8	20.1	50.4	2.1	0.4	1.2	0.4	0.5				0.1								55
45	20.9	16.0	59.6	0.6	0.5	0.9	0.4	0.8	0.1			0.1							X	60
46	22.5	13.1	60.2	0.8	0.6	1.4	0.3	0.9		X		0.1		X		X				60
47	20.2	15.8	60.4	0.8	0.6	0.9	0.5	0.7			X	X								70
48	16.7	16.4	64.3	0.6	0.2	0.4	0.3	0.9				0.2								55
49	22.9	20.0	54.2	0.4	0.3	0.8	0.3	0.9	X	0.1		0.1						X		62
50	20.8	18.4	58.4	0.2	0.3	0.3	0.5	1.0				X								65

Zir, Zircon ; Ru, Rutile ; Il, Ilmenite ; Gar, Garnet ; Tour, Tourmaline ; Mon, Monazite ; Leu +, Leucoxene plus some limonite ; Chr, Chromite ; Cass, Cassiterite ; Epi, Epidote ; Spin, Spinel ; Mag, Magnetite ; Cor, Corundum ; Hyp, Hypersthene ; Andal, Andalusite , Horn, Hornblende ; Sph, Sphene ; St, Staurolite ; Ky, Kyanite ; Ab; Abrasion (Grain Number % Rounded Zircons).

VI. DESCRIPTION OF THE MINERALS.

Zircon.—The zircon grains usually are rounded, the percentage of such grains in the samples ranging from 45 to 81%. The remainder are euhedral and subhedral. None is angular from fracture. The euhedral grains commonly are long tetragonal prisms capped at both ends by pyramids (Plate III, figure 1). Short or stumpy prisms capped by pyramids are rarer. The grains are usually clear and colourless, only occasionally brownish. Their surface often shows a high polish. Inclusions are not abundant ; they are rarer in the rounded than in the euhedral and subhedral grains. This may be because inclusions are points of weakness in the crystals, and abrasion liberates them. Inclusions are usually minute, and, when examined with a high-power magnification, most of them are seen to be irregular-shaped, hollow cavities (probably gas-filled) and dust-like spots, but a few are crystals of rutile, iron ore, monazite, zircon and apatite. Zoning has been observed in a few of the grains, but the number is very small in all the samples. The specific gravity of the zircon from Tugun beach sand is 4.68. The results of sieve analysis of three widely separated samples of zircon concentrate are shown below.

Loc.	Size of Openings in Millimetres					
	0.251-.178	.178-.152	.152-.124	.124-.104	.104-.076	< .076
Byron Bay ..	0.3%	9.0%	3.8%	63.0%	18.4%	5.5%
Cudgen ..	1.6	8.0	8.1	67.5	11.8	2.9
Tugun ..	0.5	2.4	4.4	73.9	14.9	3.8

The median diameter of the Byron Bay zircon is 0.112 mm., the Cudgen zircon 0.113 mm., and the Tugun zircon 0.112 mm.

Rutile.—The rutile grains generally are rounded, although edges of prism faces often can be seen (Plate III, fig. 2). In colour, the grains range from yellow-red through foxy-red and deep reddish-brown to black. Some " black " grains are faintly translucent in places when examined with a combination of transmitted and reflected light employing a powerful artificial light and a bull's-eye condenser. Samples of this " black " rutile submitted to chemical analysis showed that it contains up to 3.5% Fe O. Under reflected light the grains exhibit a high metallic to vitreous lustre. Striations are visible on some of the grains. As all gradations between the above colours have been observed, it is impracticable to divide the rutile into varieties based on colour. The specific gravity of the rutile from Tugun beach sand is 4.21. The results of sieve analysis of three samples of rutile concentrate are given below.

Loc.	Size of Openings in Millimetres					
	0.251-.178	.178-.152	.152-.124	.124-.104	.104-.076	< .076
Byron Bay ..	3.0%	8.7%	7.8%	70.5%	9.2%	0.8%
Cudgen ..	2.0	8.3	5.9	70.6	12.8	0.3
Tugun ..	3.8	9.9	7.3	71.7	6.9	0.2

The median diameter of the Byron Bay rutile is 0.113 mm., the Cudgen rutile 0.114 mm., and the Tugun rutile 0.114 mm. Thus, the rutile grains are approximately equal in size to the zircon grains. Qualitatively this was found to be so in all the samples.

Ilmenite.—The ilmenite grains usually are not as well rounded as the zircon and rutile grains, although ilmenite is slightly softer than these minerals. Very few of the grains, however, show crystal edges. In some, the surface presents a pitted appearance with irregular-shaped cavities. Almost all are fresh and unaltered; very few show partial alteration to leucoxene. Under reflected light they appear greyish-black, sometimes with a purplish sheen. According to Miller (1945, p. 69), an X-ray examination of the ilmenite carried out by the United States Geological Survey has shown that it is true ilmenite and not arizonite ($Fe_2O_3 3TiO_2$), the so-called " ilmenite " of Southern India. The specific gravity of the ilmenite from Tugun is 4.69. The results of sieve analysis of four widely separated samples of ilmenite concentrate are shown below.

Loc.	Size of Openings in Millimetres					
	> .178	.178-.152	.152-.124	.124-.104	.104-.076	< .076
New Brighton	1.4%	15.2%	6.4%	60.5%	12.7%	3.8%
Tugun ..	5.2	9.6	7.7	68.8	6.4	2.3
Broadbeach ..	6.4	12.4	10.8	61.5	6.9	2.0
Inskip Point ..	5.2	12.3	9.5	60.6	11.2	1.2

The median diameter of the New Brighton ilmenite is 0.116 mm., the Tugun ilmenite 0.117 mm., the Broadbeach ilmenite 0.118 mm., and the Inskip Point ilmenite 0.117 mm. The above figures indicate that the ilmenite grains on the whole are only a fraction larger than the zircon and rutile grains.

Garnet.—The garnet grains are angular and irregular in shape (see Plate I, fig. 2). Apparently they are fragments broken from larger crystals, and their angularity, which contrasts with most of the other minerals, is due to greater hardness. The grains exhibit a sub-conchoidal fracture and vitreous lustre. The surface is sometimes pitted and etched, the etching giving an irregular, hackly appearance. Mackie (1923, p. 147) has referred the occurrence of etched garnets in the sandstones of Scotland to interstratal solution, and Bramlette (1929, p. 336) has concluded that the etching is produced by acid or alkaline solutions circulating through sediments subsequent to transportation and deposition, and that it is generally an authigenic change. In colour the grains range from almost colourless to pinkish or violet-red, the most common colour being a pale watery-pink. Inclusions are not abundant; some have been identified as quartz, iron ore, zircon and rutile. The refractive index of the garnet from Tugun beach sand is very close to 1.80, and the specific gravity is 4.15. The garnet was identified as the variety almandine, which Milner (1940, p. 233) says "is the most widespread and persistent variety of garnet in detrital sediments." It is moderately magnetic. The results of a sieve analysis of a garnet concentrate from Tugun are shown below.

Loc.	Size of Openings in Millimetres					
	>.251	.251-.178	.178-.152	.152-.124	.124-.104	<.104
Tugun . .	2.5%	49.5%	25.9%	9.3%	10.8%	—

The median diameter of this garnet is 0.179 mm. The grains are much larger than the zircon, rutile and ilmenite grains. Qualitatively this was seen in all the samples, and no mineral grains larger than garnet occur in the heavy mineral concentrates.

Tourmaline.—The tourmaline grains are usually rounded, and sometimes have a high degree of sphericity. Prismatic crystals with rounded ends, some showing vertical striations, are also present. The most common colours are pale smoky-brown and pale smoky-grey. Occasionally they are yellow, blue, green and parti-coloured. Although no quantitative determination of size was carried out, most of the grains were seen to be larger than the zircon, rutile and ilmenite (Plate II, fig. 1). Inclusions are not common; they are usually bubbles and long needle-like particles without definite orientation. The round tourmaline grains are easily recognised by the comparatively low refractive index, low double refraction, and the strong pleochroism. In the subhedral grains the absorption $\omega > \epsilon$ is apparent. The prismatic grains show straight extinction.

Monazite.—The monazite grains are usually well rounded (Plate III, fig. 3), but occasionally subhedral grains occur. The grains are pale honey-yellow in colour, and have a resinous lustre. Inclusions are rare, and where present they appear mainly to be gas-filled cavities. The pecific gravity of the monazite from Tugun beach sand is 5.19. A sieve analysis gave the following result:

Loc.	Size of Openings in Millimetres			
	>.124	.124-.104	.104-.076	<.076
Tugun	—	5.5%	72.7%	21.7%

A cumulative frequency curve was constructed from the above information, and the median diameter was 0.086 mm. Thus, the monazite grains are fairly uniformly small, and usually smaller than most of the other minerals. Probably this results from the softness of monazite. A chemical analysis of a sample of monazite concentrate (98% pure) from Burleigh heavy mineral beach sand contained 7.1% of thoria.

Leucoxene.—The grains of leucoxene are dull-white to yellow-white when examined by reflected light, often having the aspect of unglazed porcelain with a rough, pitted surface. They are usually well rounded, and are non-magnetic. Leucoxene (mainly hydrated titanium dioxide) is an alteration product of titanium-bearing minerals and, according to Tyler and Marsden (1938, p. 55), it " develops from the surface weathering or hydrothermal alteration of sphene or ilmenite." The grains are approximately equal in size to the zircon and rutile grains in the concentrates.

Cassiterite.—The cassiterite grains are often subhedral or angular, and are the least well rounded of the heavy minerals with the exception of garnet (Plate III, fig. 4). The grains are variable in colour ; they are pale grey, orange, and reddish-brown. This variability is due to traces of tantalum and niobium. The colour is often irregularly distributed in the grains, and zoning is not uncommon. These characteristics were very useful in the recognition of the mineral. The specific gravity of Tugun cassiterite is 6.90. The results of sieve analysis of two widely separated samples are shown below.

Loc.	Size of Openings in Millimetres		
	0.124-.104	0.104-.076	< 0.076
Byron Bay	5.8%	80.1%	14.1%
Tugun	0.1	19.5	80.4

The median diameter of the Byron Bay cassiterite is 0.084 mm., and Tugun less than 0.076 mm. The cassiterite grains are usually smaller than all the other minerals.

Chromite.—The chromite grains are usually rounded, but occasional examples retain the characteristic octahedral form with only slight rounding at the angles. Some are opaque ; others are almost completely translucent. In contrast to brownish-black, opaque interiors, a number has greenish-brown margins which are isotropic. Under reflected light the grains exhibit a submetallic lustre, less brilliant than that of ilmenite. They are approximately equal in size to the zircon and rutile in the concentrates.

Epidote.—The epidote grains are yellowish-green, often cloudy from alteration. While some are rounded, others are prismatic and angular. They are slightly pleochroic, from pale lemon green to green, biaxial and negative, with high refractive index and high birefringence. The grains are usually slightly larger than those of zircon and rutile in the concentrates ; apparently this is related to the lower specific gravity of epidote (3.4).

Spinel.—The spinel grains are usually dark green or greenish-brown in colour ; some are bright green. They are usually rounded, but traces of the octahedral habit can be seen. This rather rare mineral is recognized by its non-magnetic or weakly magnetic properties (in contrast to the moderately magnetic garnet), and by its colour and isotropism.

Magnetite.—Very few octahedral crystals are present ; almost all are irregularly shaped. They are black, and some are altered to reddish-brown limonite. The lustre is silver-grey in reflected light.

Corundum.—The sparse corundum grains are blue, and are referred to sapphire. The colour is often unevenly distributed in the grains which are faintly pleochroic and optically uniaxial and negative. The refractive index is high, and birefringence is weak.

Hypersthene.—The rare grains of hypersthene are pale brownish-green, and the prismatic habit and distinct cleavage usually is apparent. They display characteristic pleochroism from pale green to pale pink. Inclusions of iron ore are present in some.

Andalusite.—The sparse grains of andalusite are pale pink, and occur as subhedral and rounded particles usually somewhat larger than the zircon, rutile and ilmenite. This apparently is related to the specific gravity (3.1), and hardness (7.5) of andalusite. The double refraction is low, and they are pleochroic from pale pink to colourless. Some grains are cloudy from alteration.

Hornblende.—This mineral occurs as green, fibrous, flaky grains with pleochroic absorption parallel to the horizontal crosswire. The interference colours are of low order, and the extinction angle is 13 degrees. There is good cleavage parallel to the length of the flakes.

Sphene.—The sparse grains of sphene are of characteristic brown colour, often somewhat clouded through decomposition to leucoxene. They are irregularly shaped, and not well rounded. The refractive index is very high, total extinction is absent, and the interference colours usually show a bluish tint.

Staurolite.—The staurolite grains are brown or reddish-brown in colour, and usually rounded. Some show good cleavage, and exhibit strong pleochroism, ranging from pale reddish-brown to dark brown. These properties serve for their identification. Inclusions occur, most of them appearing to be black iron ore and quartz.

Kyanite.—The very few grains of this mineral are elongate, subhedral, and rounded at the ends. They are almost colourless. Good cleavage is apparent, and some minute inclusions were seen.

Quartz.—Although the quartz grains were not examined in all the samples, the light fraction from some of them was mounted in Sirax (refractive index 1.80) and examined under the microscope. Generally they are larger than the heavy minerals, and usually subangular. Some of the grains are water-clear, but most are cloudy with minute inclusions or slightly affected by yellow iron staining. Many of the inclusions appear to be gaseous and fluid, but some prisms of tourmaline, needles of rutile, and particles of iron ore were recognised. Some of the grains exhibit strain polarisation shadows.

ABRASION.

The heavy minerals are fairly well abraded. This is apparent under the microscope even without a quantitative determination of their degree of abrasion. The results of the quantitative determination (Table III) show that there is no general trend of change in the degree of abrasion from south to north along the coast. However, the grain number percentage of rounded zircons usually is less in the samples from near the major coastline breaks, particularly to the north of them, and from about the headlands of Mesozoic sandstone. Thus, the abrasion percentages for samples 14, 15 and 16 close to the Nerang River mouth are respectively 70%, 69% and 61%, while that of sample 13 to the south, is 78%, and that of sample 17 to the north, is 80%. Similarly, the grain number percentage of rounded zircons in sample 40 from near Alexandra Headland is as low as 45%, but this decrease in abrasion again is only local.

It is of interest to note that the sand from the bore sunk with casing to 36 feet in the Eighteen Mile Swamp on North Stradbroke Island contains only 53% rounded zircons, while the samples from the beach and dunes in the neighbourhood all contain a much higher grain number percentage of rounded zircons. The sand from this cased bore has come mainly from below present sea-level, and the smaller degree of abrasion probably results from it not having been subjected as much to the action of waves and wind as the beach and dune sands. The number percentage of rounded zircon grains in the 50 samples ranges from a minimum of 45% to a maximum of 81%.

That there is no general decrease or increase in abrasion from south to north suggests that the heavy minerals have not come solely from one locality in the extreme south or north. Indeed, the definite local trends which appear to be related to major coastline breaks and sandstone headlands, suggest that additions of heavy minerals have been made to the shore at various places along the coast.

VII. GEOGRAPHIC DISTRIBUTION OF THE HEAVY MINERALS.

The Table of Mineral Analyses shows that the heavy mineral beach sand concentrates are composed essentially of zircon, rutile and ilmenite. All the other minerals together usually make up less than 5% of the total heavy mineral weight percentage. However, there are large changes in the individual weight percentages of zircon, rutile and ilmenite in the concentrates from south to north along the coast.

In the area to the south of the Nerang River zircon is the most abundant mineral, usually with rutile in second place and ilmenite third. However, a gradual decrease in the percentage of zircon and a slight increase in the percentages of rutile and ilmenite from south to north is noticeable in this area.

On South and North Stradbroke Islands the weight percentages of zircon, rutile and ilmenite in the concentrates are approximately equal, except for a slight decrease in the zircon and an increase in the ilmenite content northwards. Throughout this area, the rutile content remains almost stationary. Therefore, on Stradbroke Island the zircon content usually is lower, and the rutile and ilmenite contents slightly higher, than in the concentrates from south of the Nerang River mouth.

On Moreton Island and in all places further north ilmenite is the predominant heavy mineral. It forms over 50% of the heavy minerals in all the samples examined, and the weight percentages of zircon and rutile are approximately equal. In the stretch of coastline northwards from the South Passage, the weight percentages of zircon and rutile generally are each less than 25%, with rutile slightly less than zircon. Throughout this area the most striking trend in the distribution of the heavy minerals is the decrease in zircon content and the increase in ilmenite northwards.

The distribution of the other minerals is rather erratic, but several definite features are evident. The most conspicuous is the much higher garnet content in the neighbourhood of the headlands of Mesozoic sandstone which occur at intervals along the coast from Cape Moreton northwards. To the south the garnet content is not greater than 1.4% in any of the samples studied. Northwards, however, the garnet content is as high as 5.2% in the Caloundra Head beach sand, 8.3% at Alexandra

Headland, 7.1% at Pt. Arkwright, 3.5% at Paradise Caves (Coolum Beach), 1.5% at Noosa Head, and 2.1% in the sample from 3 miles N. of the Noosa River mouth. Northwards from Double Island Point, where there are no further outcrops of Mesozoic sandstone, the garnet content is again low, less than 1% in the samples studied.

Another feature is the much higher tourmaline content compared with garnet in the samples from Stradbroke Island. Elsewhere the garnet content is usually slightly greater than tourmaline ; on Stradbroke Island the tourmaline content is generally more than 1.5%, while the garnet is less than 0.5% and is as low as 0.1% in one sample. This may result from the greater stability of tourmaline. On Stradbroke Island no possible source rocks outcrop along the coast, and the heavy minerals appear to have had a long history since liberation.

Monazite, like garnet, is usually more abundant in the vicinity of outcrops of Mesozoic sandstone along the coast. For example, it is as much as 2.4% in the Caloundra Head sample, 1.1% at Alexandra Headland, 1.5% at Pt. Arkwright, 1.1% at Paradise Caves (Coolum Beach), 1.0% at Noosa Head, 1.2% in the sample from just N. of Noosa, and 1.4% in the Double Island Point sample. In almost all other localities the monazite content is less than 1%, and on North Stradbroke Island it is usually less than 0.5%.

The Table of Mineral Analyses shows that epidote is often present in samples in which the tourmaline content is higher than usual. This association apparently is related to the similar, low specific gravity of these two minerals. Although chromite is irregular in its abundance, it shows a drop in quantity in the Stradbroke Island samples. The distribution of other minerals is irregular. Very few grains of corundum, hypersthene, andalusite, hornblende, sphene, staurolite and kyanite are present in any of the samples.

VIII. ORIGIN OF THE HEAVY MINERALS.

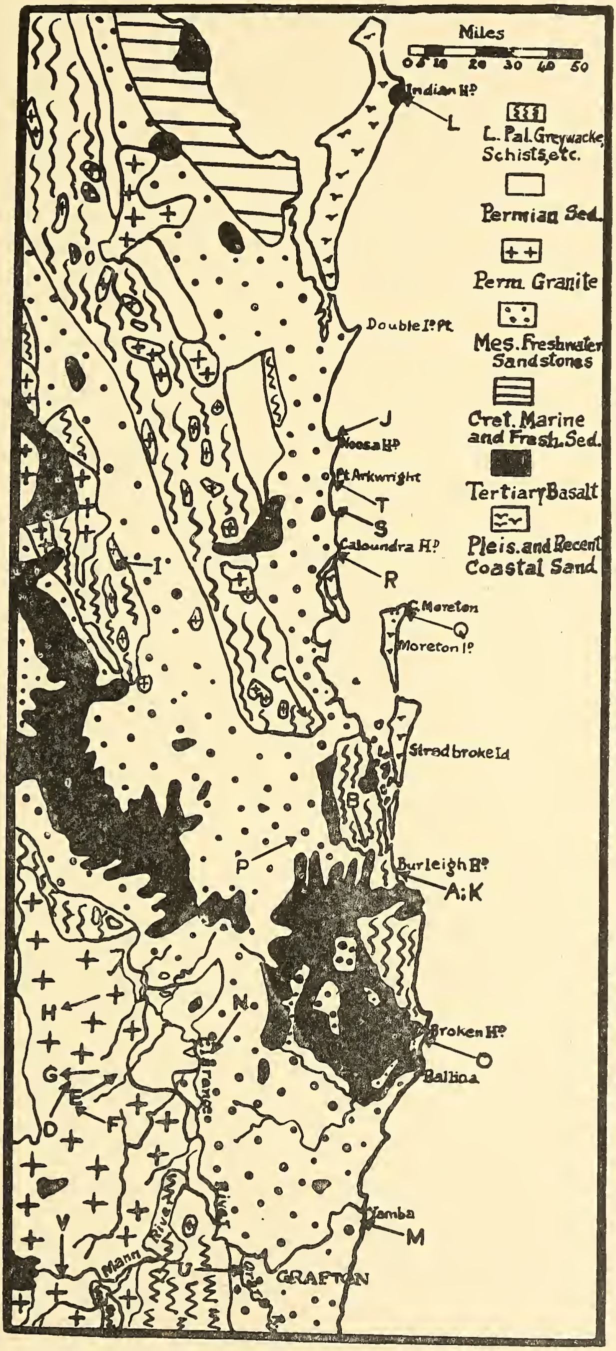
Samples from outcrops of possible source-rocks in south-eastern Queensland and northern New South Wales were examined in the hope of obtaining evidence concerning the origin of the heavy minerals. They were broken down in the manner described above, and their heavy mineral assemblages studied under the microscope.

River sand concentrates also were examined from streams entering the sea between Yamba in northern New South Wales and Caloundra in southern Queensland. Samples were panned from bars and banks, and from the shallow, upper reaches of channels and the beds of streams.

Geology of the Region.

The following brief account of the geology of the region has been prepared from a number of papers, and from the field observations of the writer. For the sake of clarity, Queensland rivers have been omitted from the geological map (Text-fig. 5).

The basement rocks outcrop along the coast in the southern part of the region. They make up, in some places with Tertiary basalt, all the headlands as far north as South Nobby Headland. They are low-rank metamorphics (greywackes, slates, quartzites, jaspers and phyllites) of Lower Palaeozoic age, which were originally laid down as sediments in the Tasman Geosyncline. From the South Coast (New South Wales



TEXT-FIGURE 5.—GEOLOGICAL MAP OF REGION, SHOWING PLACE OF COLLECTION OF ROCK SAMPLES STUDIED.

border to Southport) area of Queensland northwards, these rocks trend NNW. away from the coast. In SE. Queensland they are known collectively as the Brisbane Schists, and the name Neranleigh Series has been given to the subdivision consisting largely of greywackes.

Further inland, in the southern half of the area, there is a small outcrop of Devonian basic volcanics, chert and limestone, and there are some areas of Permian sediments, the largest of which is in the Drake-Boorook district. In the northern half of the area, away from the coast, there are also some small areas of Permian sediments which are mainly of shallow-water marine origin, but near Warwick, freshwater deposits are interbedded.

In late Permian times, these Palaeozoic metamorphic and sedimentary rocks were intruded by numerous granitic masses. By far the largest of these is the New England-Stanthorpe composite batholith. It is centred about Tenterfield and covers an area of several thousand square miles. Andrews (1907) has recognised a number of phase-types in this mass—namely, " Grey Felspar Porphyries," " Blue Granite," " Sphene Granite Porphyry," and " Coarse Acid or Tin Granite "—the main intrusions becoming progressively more acid and having their maximum development in the northern part of the mass. An extensive development of greisen and pegmatite occurs about the peripheries of these acid intrusions, and with them are associated important ore deposits containing tin, bismuth, tungsten and molybdenum, as well as monazite, gold and other valuable minerals (Andrews, 1905 a ; 1905 b). The granitic masses further north are similar but smaller in area (Bryan, 1922, pp. 148-157). Probably some of them were comagmatic. At least two of these granitic masses (near Kingaroy and Mount Perry) are known to have small deposits of rutile and ilmenite around their margins. According to Cribb (1943, p. 39) the Kingaroy mass is a medium-grained biotite granite, and in the neighbourhood of the deposits it gradually assumes a gneissic structure. " The granite is intruded by dykes of pegmatite and aplite, usually of small size. Black tourmaline is abundant in the former in association with white felspar, quartz, and muscovite." The rutile is seen now mainly as shoad material, " occurring in grains and pieces, the larger sizes usually with an elongated outline up to 1½ inches long, and generally exhibiting vestiges of crystal faces with rounded angles. Forms present include pyramids and 1st and 2nd order prisms." Some ilmenite is associated with the reddish-brown rutile, and both are found as sparsely scattered nodules surrounded by thin segregations of biotite in the granite. Fisher (1945) states that the rutile near Mount Perry occurs in small veins less than 8 inches wide associated with finely granular quartz in the granite. According to Morton (1946), small rutile lode deposits also are found associated with Permian pegmatites in North Queensland. Around the granitic masses, contact metamorphic rocks such as garnet hornfels and spotted slate are often present.

Most of these late Permian granitic bodies must have extended to very near the surface, as they were unroofed in at least Middle Triassic times. Their injection was associated with a major movement of uplift, accompanied by folding and mountain building. The Palaeozoic Tasman Geosyncline was finally drained, and freshwater lakes were left in its place. The position of these lakes in Upper Triassic and Jurassic times marginal to the large New England-Stanthorpe granitic mass, and the other granitic masses in the area, is proof that relatively high land existed there. In places the lakes extended some distance east of the present coastline, and it is possible that granitic masses also were associated with high land along an eastern margin now beneath the Pacific Ocean. Earth-movements after the close of the Jurassic drained the lakes, and the rocks of the area in places were considerably folded.

A large part of this coastal area is covered by these Mesozoic freshwater sediments. In Queensland the Upper Triassic lacustrine sediments are known as the Ipswich and Bundamba Series, while those of Jurassic age are the Walloon Series. In northern New South Wales the equivalents of the Bundamba and Walloon Series are known as the Clarence Series. Near the margins of both the Walloon and the Clarence Series, these Jurassic sediments can be seen resting on well-eroded, Permian granitic surfaces. In the Maryborough-Bundaberg district, there is a small belt of shallow-water, marine and freshwater sediments of Cretaceous age. At Point Arkwright and Noosa Head the Jurassic sandstones have been intruded by very small masses of granodiorite of late Mesozoic age.

In many places these Palaeozoic and Mesozoic rocks are overlain by Tertiary volcanics. These are mainly basic in composition (andesites and basalts), and are principally Pliocene in age. They are particularly abundant in the region about the Queensland-New South Wales border, and formerly covered much of the New England Tableland. They outcrop along the coast at such places as Fingal Head, Point Danger, Burleigh Head, Double Island Point, and Indian Head.

The Pliocene basalts were deeply dissected following a major movement of uplift at the close of the Tertiary, and the Mesozoic and Palaeozoic rocks which underlay them were exposed again in many places. The forces of erosion were so active that the basalts were removed almost completely from large areas, and occur only as isolated, residual cappings at the present time.

The streams traversing these rocks are quick-flowing in their upper reaches, but except in times of flood, they are rather sluggish in their lower reaches. Stream-deposits of economic value occur. Alluvial tin is worked in the upper reaches of the Clarence River, and zircon, monazite, topaz, garnet, spinel and sapphires are recovered, as well as some gold and platinum.

Pleistocene and Recent beach and dune sands cover much of the country fringing the present coastline. The large coastal islands are almost entirely covered with sand-dunes, and only at a few places close to sea-level do rocks outcrop.

NATURE AND PLACES OF COLLECTION OF ROCK AND RIVER SAND SAMPLES.

The location of the places where the rock samples and river sands U and V were collected is shown in Text-figure 5, and those of the other river sands in Text-figure 1.

ROCK SAMPLES.

A. Greywacke from Neranleigh Series exposure in main road in cutting, Burleigh Head.

B. Greywacke from exposure in railway cutting, 1½ miles S. of Nerang railway station. In type area of Neranleigh Series.

C. Greywacke from Neranleigh Series exposure at Brookfield, near Brisbane.

D. Coarse-grained, acid New England granite from outcrop alongside New England Highway, N. of Tenterfield.

E. Pegmatite near periphery of New England batholith, NE. of Tenterfield.

F. " Basic " blue granite from outcrop, 2 miles E. of Tenterfield.

G. Sphene granite-porphyry from outcrop near Wallangarra.

H. Coarse-grained Permian granite from Stanthorpe.

I. Permian granite from Yarraman, S. of Nanango.

J. Late Cretaceous granodiorite intruding Jurassic sandstone at Noosa Heads.

K. Tertiary andesitic-basalt capping Ordovician greywacke at Burleigh Head.

L. Tertiary basalt from Indian Head.

M. Lower Jurassic sandstone from outcrop near Yamba.

N. Clarence Series sandstone from exposure in road cutting near Tabulam.

O. Lower Jurassic Clarence Series sandstone (slightly weathered) from exposure in road cutting near Broken Head, about 4 miles S. of Byron Bay.

P. Upper Triassic Bundamba Series sandstone from outcrop near Beaudesert, in Logan River valley.

Q. Upper Triassic sandstone from Cape Moreton.

R. Upper Triassic Bundamba Series sandstone from Caloundra Head.

S. Jurassic sandstone from Alexandra Headland.

T. Jurassic sandstone from Point Arkwright.

RIVER SAND SAMPLES.

U. Oraro River, just W. of Grafton. The Oraro River entirely traverses Clarence Series strata.

V. Mann River, on Glen Innes-Grafton road 78½ miles from Grafton within the outcrop of the New England granitic mass.

W. Bluff River, between Tenterfield and Glen Innes in the heart of New England granitic mass.

X. Sandy Creek, a tributary of the Clarence River, between Tabulam and Tenterfield. On New England granite, not far from the eastern edge of the batholith.

Y. Plumbago Creek at Drake in the centre of a small block of Permian sediments, immediately E. of New England granitic mass.

Z. Tributary of the Richmond River traversing area of Clarence Series strata, between Tabulam and Casino. Relatively large quantities of heavy mineral concentrate were obtained at each panning.

ZA. Richmond River at Casino. The concentrate was obtained by panning river sand resting on Clarence Series sandstone. Tertiary basalt is very abundant in the vicinity.

ZB. Tweed River near Uki. The Lower Palaeozoic metamorphics are intruded by a small Permian plutonic mass and overlain in many places by Tertiary volcanics in the region.

ZC. Currumbin Creek, which flows through Lower Palaeozoic greywackes and slates capped by Tertiary basalts. Only a small quantity of heavy mineral concentrates was obtained at each panning.

ZD. Brisbane River at Moggill. In an area of Upper Triassic sandstones and Lower Palaeozoic metamorphics intruded by some Permian granitic masses.

ZE. Stanley River at Somerset Dam. Rocks mainly andesitic material, but some plutonic rocks of intermediate composition present.

ANALYSES OF HEAVY MINERAL FRACTIONS OF THE ROCK SAMPLES.

In the accompanying Table the minerals are arranged in order similar to Table III and the same abbreviations are used, the symbol " x " indicating that the mineral is present in amounts less than 0.1%. For convenience, the degree of mineral abrasion in the metamorphic and sedimentary rocks, calculated as the grain number percentage of rounded zircons, is incorporated in this Table. Additional abbreviations used are :—

I.F., Index-figure ; Il+, Ilmenite plus chromite when present ; Pyrox, Pyroxene ; Horn+, Hornblende plus some chlorite ; Ap, Apatite ; Bio+, Biotite plus some chlorite ; Py, Pyrites ; To, Topaz ; Ana, Anatase.

DISCUSSION.

(*a*). *Greywackes.*

The index-figures in the preceding Table show that the weight percentage of heavy minerals in the greywacke samples is exceedingly small, less than 0.01%. The grain size is smaller than that of any of the beach sands. In sample A the mean of the zircon intermediate diameters was 0.063 mm., the largest 0.086 mm., and the smallest 0.049 mm. In sample B the mean was 0.064 mm., the largest 0.098 mm., and the smallest 0.036 mm., while in sample C the mean was only 0.055 mm., the largest 0.061 mm., and the smallest 0.049 mm. The means of 100 intermediate diameters each of the beach sand zircon from Byron Bay, Cudgen and Tugun were 0.114 mm., 0.115 mm., and 0.114 mm. respectively, which is practically the same as the median diameters. The zircon size in the greywacke samples is therefore considerably smaller than in the beach sands (Plate III, fig. 1, and Plate V, fig. 1). The degree of zircon abrasion (Table IV) usually is not as great as in the beach sand concentrates.

The heavy mineral assemblages of the greywackes are made up essentially of zircon, ilmenite, leucoxene and tourmaline. All the other minerals, such as rutile, garnet, cassiterite, epidote, spinel, kyanite and anatase are very scarce, and together form less than about 5%.

These results, particularly the exceedingly small heavy mineral content, the small grain size, the heavy mineral composition, and certain mineralogical properties such as the large number of dusky zircon grains, indicate that the greywackes have not played a major role as a contributor of the heavy minerals in the beach sand deposits.

(*b*). *Granitic Rocks.*

The index-figures in Table IV show that the weight percentage of heavy minerals in some of the granitic samples is comparatively large. This is mainly because the ferromagnesian silicate minerals, which have

TABLE IV.—MINERAL ANALYSES OF HEAVY MINERAL FRACTIONS OF THE ROCK SAMPLES, AND ABRASION GRAIN NUMBER PERCENTAGES.

(The figures below the horizontal line are mineral weight percentages.)

No.	I.F.	Zir	Ru	Il +	Gar	Tour	Mon	Leu +	Cass	Epi	Mag	Spin	Pyrox	Horn +	Sph	Ap	Bio +	Py	To	Ana	Ky	Ab
A	< .01	C	S	S	S	C		C	S	S		S										66
B	< .01	a	S	C	S	c		c												S	S	22
C	< .01	a	S	C	S	c		c	S												S	42
D	4.9	c	S	S		S	S		S		c			c	S	s	A	S	S	S		
E	3.2	c	S	S		S	S				c			c		s	A	S				
F	19.0	s	S	s						S	s			C	S	c	a			S		
G	7.8	s		S				S	S		s			A	C	c	c					
H	2.7	c		S	S	S				S	c			s	S	S	A			S		
I	4.1	c	S	S		S	S				s			c		s	A					
J	11.5	S	S	s							S			A	S	C	S					
K	58.3			c							S		A			S						
L	62.8			c							S		A			S						
M	0.7	33.1	14.0	10.1	27.5	2.9	3.2	8.8	0.1	0.2		0.1								X		45
N	0.8	29.0	37.9	22.4	0.9	2.0	6.1	1.4	0.3	0.1									X			54
O	1.5	21.5	20.0	11.3	1.2	2.3	1.2	41.0	0.1	0.4		0.5			0.3				X			44
P	0.1	32.2	14.9	10.8	32.6	1.1	2.4	5.5		0.3										0.1		46
Q	< 0.1	31.9	15.7	18.5	20.1	3.9	2.8	6.8		0.3												32
R	0.1	8.2	14.0	10.0	58.8	3.8	2.3	2.3		0.2		0.1		0.2								25
S	0.1	4.5	4.0	2.8	85.4	1.2	1.7	0.4		0.1												43
T	< 0.1	32.5	40.5	18.7	2.8	1.5	3.5	0.4				0.1				X			X			35

A = Very abundant ; a = Abundant ; C = Very common ; c = Common ; s = Scarce ; S = Very scarce.

specific gravities greater than 2.86, are included. These ferromagnesian silicates are the heavy essential minerals, as opposed to the heavy accessory minerals. Because of the influence of these minerals upon the index-figures, it is natural that the basic " granite " and granodiorite samples have the highest index-figures. There is a wide range in the index-figures of the five samples from the New England batholith, apparently as a result of contamination by assimilation of foreign material, and differentiation of the mass.

The means of 100 zircon intermediate diameters in the seven samples are :—Sample D, 0.115 mm.; E, 0.112 mm.; F, 0.125 mm.; G, 0.105 mm.; H, 0.114 mm.; I, 0.110 mm.; J, 0.100 mm.

Thus, the zircon in the six Permian granitic samples is either slightly larger (sample F), or almost exactly the same size (samples D, E, G, H and I) as the beach sand zircon. The sparse zircon in the Cretaceous granodiorite (sample J) is smaller.

The more abundant heavy accessory minerals in the seven granitic rocks are zircon, apatite, sphene, magnetite and ilmenite. The heavy essential minerals are biotite and hornblende. In four of the rocks (the more acidic), zircon is by far the most abundant mineral in the non-magnetic, heavy mineral fraction. That it is seldom seen in thin sections apparently is due partly to the very small area of such sections, and partly to the fact that it is prone to break away during the grinding preparations. It is an early product of crystallization and is often surrounded by an air pocket.

In three of the rocks apatite is the most abundant non-magnetic heavy mineral. Sphene is common in the sphene granite-porphyry, and is visible even in the hand specimen. In four of the other granitic rocks also it was found, but very scarce. Rutile is not abundant, but occurs in five samples. In two samples, magnetite is not in excess of ilmenite. While pneumatolytic minerals are not abundant, tourmaline, cassiterite, monazite, topaz, and anatase are present in the Permian samples. They occur more in the acidic samples, tourmaline and monazite being the most widespread. The presence of pink garnet (almandine) in sample H from Stanthorpe is suggestive of rock assimilation and contamination near the margin of the batholith.

The geology of the region indicates that the most feasible major primary source for the beach sand heavy minerals are the Permian granitic rocks. The fact that zircon of very similar size and appearance to the beach sand zircon is common in the six Permian granitic samples, and that rutile, ilmenite, magnetite, monazite, tourmaline, cassiterite, epidote, hornblende, sphene, and some pink garnet are also present is confirmatory evidence. The two very small outcrops of late Cretaceous granodiorite, at Point Arkwright and nearby Noosa, could not have played any major role as contributors of the beach sand heavy minerals. The very sparse zircon in the granodiorite from near Point Arkwright (sample J) is of a smaller size than the beach sand zircon, while more of the grains have a cloudy or dusky appearance. Pneumatolytic minerals such as tourmaline, monazite, topaz, cassiterite and anatase are also lacking from the heavy mineral assemblage.

(*c*). *Basalts.*

As it was realised that basic volcanic rocks could not be important source rocks for most of the heavy minerals in the beach sands, only two samples of Tertiary basalt from the area were chosen for examination.

They were the Burleigh Head andesitic basalt (sample K) and the Indian Head basalt (sample L). Table IV shows that the index-figures for these rocks are high. This is chiefly because of the presence of a great quantity of the heavy essential mineral, augite. It is the most abundant heavy mineral in both samples. Richards (1916, p. 174) examined thin sections of the Burleigh basalt and stated that " the augite occurs in sub-ophitic rounded patches but occasionally in long patches 1 mm. in length." Olivine is not present.

The heavy accessory minerals in both samples are mostly black iron-ore, although some apatite is present. Treatment with the electro-magnet showed that the bulk of the iron-ore material is moderately magnetic, and it has been referred to ilmenite, although a very small amount of chromite may be present. A small amount of the material is highly magnetic, and this has been referred to magnetite. In thin sections of these basalts the iron ore has been found to occur in granules and in rods, the latter averaging 0.4 mm. in length. It will be recalled that Tertiary volcanics, particularly those of basic composition, are very extensively developed in certain parts of the area, while evidence indicates that they formerly covered a much greater area than at present. From their distribution, and the fact that ilmenite is common in the samples, it is apparent that they have contributed at least some of the ilmenite in the beach sands, and it is possible that they may be an important source rock for this mineral.

(*d*). *Sandstones.*

The weight percentage of heavy minerals in the eight samples of Mesozoic freshwater sandstone varies from less than 0.1% to as much as 1.5%, and is highest in the Clarence Series sandstones. In the Upper Triassic Bundamba sandstones and the Jurassic sandstones from southern Queensland the weight percentage of heavy minerals is 0.1% or less. This is comparable in amount with that of the freshwater Narrabeen sandstones from near Sydney, studied by Culey (1932). Since the weight percentages of heavy minerals in the three Clarence Series samples are 0.7%, 0.8% and 1.5%, it would seem that these freshwater sandstones are particularly rich in heavy minerals.

Unfortunately, it is not possible at present to give the exact age and position in the stratigraphic column of the sandstone samples studied. This is because of the sporadic and often poor nature of the sandstone outcrops, the lithological similarity of most of the sandstones, the paucity of exposures containing fossiliferous shale bands, and the scarcity of detailed geological mapping in the region.

Even without a quantitative determination of size, it is apparent that the grain size of the heavy minerals generally is slightly larger than those of the beach sands. The means of 100 zircon intermediate diameters in the eight samples were found to be :—Sample M, 0.110 mm.; N, 0.152 mm.; O, 0.120 mm.; P, 0.115 mm.; Q, 0.125 mm.; R, 0.120 mm.; S, 0.126 mm.; T, 0.130 mm.

Thus, the zircon usually is slightly larger than the beach sand zircon, although in samples M and P it is of about the same size. Microscopic examination of the heavy mineral assemblages has shown that the minerals are not as rounded as those of the beach sand deposits. The degree of zircon abrasion (Table IV) is clearly less. It will be noticed that the sandstone samples collected from near beach concentrates have lower grain number percentages of rounded zircons than the adjacent concentrates. The heavy minerals usually do not appear to be as well sorted as those of the beach sand concentrates (see Plate V, figs. 3 and 4).

The heavy mineral assemblages of the sandstones are made up essentially of the same suite of minerals as the beach sand concentrates, but the proportions are somewhat different. Although the weight percentage of zircon in six of the samples is greater than 20%, it is the predominant heavy mineral in only samples M and Q. Rutile is the most abundant heavy mineral in samples N and T. In N the content is as much as 37.9%, and in T it is as high as 40.5%. The iron-ore content ranges from 2.8% to 22.4%, and it is less than 20% in seven of the eight samples. The opaque iron ores are not the most abundant heavy minerals in any sample.

Garnet is the most abundant heavy mineral in samples P, R and S, and its weight percentage is more than 25% in four of the samples. In the Caloundra Head sample it is 58.8%, and in the Alexandra Headland sample it is as much as 85.4%. As already stated, the garnet content in the beach sand concentrates usually is markedly higher in the neighbourhood of the outcrops of Mesozoic sandstone, but it is much less than that in the sandstone assemblages. The percentage of tourmaline ranges from 1.1% to 3.9%, and it is usually a little greater than in the beach sand concentrates. The content of monazite is generally greater than that in the beach sand concentrates. It ranges from 1.7% to as much as 6.1%.

The percentage of leucoxene (plus some limonite) ranges from 0.4% to 41%, but it is greater than 10% in only one sample. The content is generally higher than in the beach sand concentrates, and the weight percentage of 41.0% in sample O is conspicuously higher. Sample O is from an exposure in a road cutting, and weathering *in situ* may be partly responsible for this high leucoxene percentage. Nevertheless, an ilmenite content or leucoxene source originally much greater than that of any of the other sandstones is indicated. The content of epidote is slightly greater than in the beach sand concentrates.

From the very rich content of heavy minerals in some of these sandstones, the larger grain size, the less abraded and less well-sorted nature of the heavy minerals, the presence of essentially the same suite as in the beach sands, the striking similarity in appearance under the microscope of the minerals (see below) with those in the beach sands, and the absence of any other likely major source rock in the vicinity, it is concluded that the freshwater Mesozoic sandstones are the immediate source rocks of most of the heavy minerals in the coastal sand deposits. The differences in the proportions of the various mineral species in the sandstone heavy assemblages and the beach sand concentrates apparently are due, in part, to the fact that much of the ilmenite presumably is derived from the Tertiary basalts of the region. The amount varies. The differences apparently are due in part also to the varying degree of stability of the heavy minerals, and to the fact that in the coastal sands they have been through at least one more cycle of erosion, transportation and deposition. As Pettijohn (1941, pp. 610-625) and Lincoln and Clarissa Dryden (1946, pp. 91-96) have shown, the resistance of garnet to weathering is much less than that of zircon, rutile, tourmaline and monazite. This would explain the much lower percentage of garnet in the beach sand concentrates than in the nearby sandstones. Similarly, the greater abundance of zircon in the beach sand concentrates must be partly due to its chemical and physical stability, which is known to be extremely great.

Study of River Sand Concentrates.

In most cases, the amount of heavy minerals in the river sands was small, and in some it was exceedingly small. Any light minerals in the panned samples were removed with bromoform. Mechanical analyses of all except samples Y and ZD, which were too small for accurate sieving, were then carried out in the same way as for the panned beach sand concentrates. The results are given in Table V, and the quartiles, medians, and coefficients of sorting in Table VI.

Table V.—Mechanical Analyses of Heavy Mineral Sand Concentrates.

No.	Size of openings in millimetres						
	>.251	.251–.178	.178–.152	.152–.124	.124–.104	.104–.076	<.076
	%	%	%	%	%	%	%
U	22.2	40.8	14.8	5.3	3.4	12.7	0.7
V	9.9	27.9	16.5	8.0	12.0	25.4	0.3
W	—	14.2	16.0	11.8	5.0	52.6	0.4
X	7.2	40.4	20.4	10.1	0.3	21.5	0.1
Z	3.2	21.6	17.0	10.4	0.9	44.1	2.7
ZA	—	5.0	8.8	8.5	2.1	67.4	8.2
ZB	90.1	8.7	0.5	0.2	0.1	0.3	0.1
ZC	0.6	3.1	5.1	3.0	2.1	66.2	19.9
ZE	64.5	28.9	3.5	0.9	0.2	1.9	0.1

TABLE VI.—First and Third Quartiles, Medians, and Coefficients of Sorting of the Heavy Mineral River Sand Concentrates.

No.	Q1	M	Q3	So
		Millimetres		
U	.250	.200	.158	1.26
V	.208	.160	.104	1.41
W	.161	.102	.088	1.35
X	.218	.174	.134	1.27
Z	.178	.130	.088	1.41
ZA	.104	.092	.082	1.13
ZB	>.251	>.251	>.251	—
ZC	.100	.088	.078	1.13
ZE	>.251	>.251	.224	—

Samples ZB and ZE differ from the beach sand concentrates in that the maximum sieve-fraction is that retained on the B.S.S. 60 sieve (aperture size 0.251 mm.). This size fraction proved to be mainly ilmenite. Samples U, V and X have maximum sieve-fraction percentages in the 0.251 mm. to 0.178 mm. grade size. This is larger than that of all except three of the beach sand concentrates obtained from sands adjacent to coastal outcrops of Mesozoic sandstone. The other four river sand concentrates have maximum sieve-fraction percentages in the 0.104 mm. to 0.076 mm. grade size.

The median diameters of the heavy mineral river sand concentrates range from a minimum of 0.088 mm., in the Currumbin Creek sample, to more than 0.251 mm. in samples from the upper reaches of the Tweed and Brisbane Rivers. These are larger than any of the panned beach sand medians, but the median of samples from Currumbin Creek, Bluff River, and Richmond River (ZA) are smaller. The medians of samples U, V and X from tributaries of the Clarence River, and Z (from the Richmond River) are within the size range limits of the heavy mineral beach sand medians, but all are larger than the average. It is of interest to note that the median of sample X, from near the margin of the New England granitic mass, is as much as 0.174 mm., while that of sample W, from the heart of the eroded batholith, is only 0.102 mm.

Coefficients of sorting for only seven of the river sand concentrates are given. Quartiles could not be determined for two of the samples as most of their bulk was retained on the coarsest sieve employed. The coefficients range from 1.13 to 1.41 ; that is, the heavy minerals are generally not as well sorted as those of the beach sand samples. The least well-sorted heavy minerals are those of samples V, W and Z, all from within the outcrop of the New England granitic mass or close to its margin.

Log skewness calculations were not made, as it was felt that they would be of little practical value. However, some knowledge of the skewness of the heavy mineral samples can be obtained from Tables V and VI.

The mineral analyses are shown in Table VII, together with the degree of mineral abrasion (calculated as the grain number percentage of rounded zircons). The abbreviations used are the same as those in Tables III and IV.

DISCUSSION.

The degree of abrasion of the heavy mineral river sands is usually much less than that of the beach sands. Table VII shows that, with the exception of sample U, the grain number percentage of rounded zircons in all samples is lower than that in the beach concentrates. The river sands containing the least number of rounded zircon grains are those which appear to have been derived directly from the weathering of Permian granitic rocks. An increase in abrasion in the river sands away from the granitic outcrops, particularly in the regions covered by later, freshwater sedimentary rocks is apparent from the grain number percentages.

The heavy minerals comprise essentially the same species as are found in the beach sands. However, there are fairly large differences in the weight percentages of some of the minerals compared with those of the beach, and in the number of mineral species in some of the river sands.

In the samples which appear to have been derived from the disintegration of the Permian granitic rocks, more or less *in situ*, the percentage of magnetite is high. In the other samples, however, the content is low. The fact that it is rare in the heavy mineral beach sands may be taken as indicating a greater distance from its primary source. As well as high magnetite contents, all except one of the samples from within and near the granitic outcrops contain more than 30% of ilmenite. Probably some of this ilmenite came from the Tertiary basalts in the area. In other samples, ilmenite is much more abundant than magnetite. In sample ZC from Currumbin Creek, which drains an area consisting only of Ordovician greywacke and Tertiary basalt, the ilmenite

TABLE VII.—MINERAL ANALYSES OF HEAVY MINERAL RIVER SAND CONCENTRATES IN PERCENTAGES BY WEIGHT, AND ABRASION GRAIN NUMBER PERCENTAGES.

No.	Zir	Ru	Il+	Gar	Tour	Mon	Leu+	Mag	Cass	Epi	Spin	Aug	Horn	Sph	Ana	Ap	To	Ab
U	43.7	19.0	21.7	6.7	0.5	5.5	1.3	0.2	0.4	0.5	X				X		0.4	60
V	5.2	2.1	5.7	0.6	1.0	0.6	—	72.1		0.2			10.1	2.4				14
W	18.0	1.1	32.7	0.3	0.4	0.9	—	42.9		0.7			1.5	1.5	0.1	X	0.2	6
X	10.0	3.5	63.8	1.0	0.1	1.0	—	11.8					5.5	3.5		X	0.2	3
Y	21.3	11.5	46.5	3.1	0.2	5.1	2.0	12.0			X						0.3	23
Z	38.0	17.7	29.9	6.3	0.5	6.3	—	1.0	0.3		X					X		23
ZA	4.8	4.2	60.9	7.6	0.5	0.7	—	20.2				1.1						23
ZB	2.1	—	53.1	4.1	—	—	—	38.5				2.0						—
ZC	6.2	1.0	86.4	0.3	—	—	0.3	0.9				4.9						30
ZD	6.5	5.5	13.7	2.7	0.9	0.9	—	25.1		0.9	X	5.5	35.2	2.7		X		17
ZE	1.5	—	40.6	0.9	—	0.8	—	46.7		2.6		1.0	5.0	0.8				—

makes up 86.4% of the heavy minerals, and the fact that the grains are not rounded suggests that it is derived from the basalt and not from the greywacke.

The contents of hornblende and sphene are much greater in the sands from within and near the granitic masses than in those from other places. This, together with the distribution of topaz, is apparently related to the comparatively low stability of these minerals. The weight percentages of zircon and rutile, together with those of garnet and monazite in particular, are greater in the river sands collected from regions of Mesozoic sandstone than from the granitic areas. This is apparently due to the gradual removal of less stable minerals such as magnetite, hornblende, augite, sphene, apatite and topaz.

From the above it is clear that the major rivers which flow chiefly through regions of Mesozoic sandstone bring to the sea essentially the same assemblage of heavy minerals as occur in the beach sands, and that the streams which drain areas where Tertiary basalts are widespread transport a much larger proportion of ilmenite seawards. The rivers in the southern part of the area appear to bring down to the coast less ilmenite than do those to the north. It is unlikely that any great quantity of the heavy mineral material derived directly from weathering of the Permian granitic rocks reaches the Pacific Ocean at the present time.

The mineralogical composition, size-distribution, sorting, and abrasion of the heavy mineral river sand concentrates, as well as the appearance of the heavy minerals under the microscope indicate that the beach sand heavy minerals could have been derived largely from the rocks in the hinterland and transported to the sea by the present coastal streams. Most of the coastal streams are rather slow-flowing in their lower reaches, but their rate of flow increases considerably following periods of heavy rainfall, and they are subject to severe floods. Large quantities of detrital material are then carried to the Pacific Ocean. Even under normal conditions, tidal currents help to carry some sands from the lower reaches of the rivers out to sea.

Although the coastal rivers may not always have occupied their present courses, Craft (1933) considered that the positions of the major streams were approximately as at present at least before the outpourings of basic lava in the Pliocene. The rate of flow would be great after movements of uplift and rejuvenation which occurred in Tertiary times, and vast amounts of heavy mineral material would be brought down to the sea and distributed along the coast.

Descriptions of the Heavy Minerals in the Rock and River Sand Samples.

Zircon.

Greywackes (Plate V, fig. 1). Apart from the small size, the most distinctive feature is the relatively large number of dusky or cloudy grains. Unlike the beach sand zircon, many of the grains are crowded with inclusions which give them this cloudy appearance, and a large number of them show zoning.

Granitic Rocks (Plate V, fig. 2). Most of the zircons are long tetragonal prisms capped at both ends by pyramids. A small number is corroded, and some are well rounded and have a "waterworn" appearance. While these may be xenocrysts, it is possible that they may all be the result of magmatic chemical corrosion subsequent to crystallization. Almost all are colourless, but a few crystals are pale brownish. Inclusions are not common ; a few are crowded with them, and have a cloudy appearance contrasting with the comparative clarity of the others. Some of the inclusions are black iron ore (probably ilmenite), rutile, apatite, and minute zircons, but many are irregularly-shaped cavities and dust-like spots. A small number of the crystals show zoning. This is more common in those which have a cloudy appearance.

Sandstones (Plate V, figs. 3 and 4). Apart from the slightly larger grain size and the lower degree of abrasion, the zircon is identical in all respects with the beach sand zircon.

River Sands. In the stream sands from the New England area, almost perfect euhedral zircons, with intermediate diameters as great as 8 mm., were handpicked from the concentrate. Those in the sands from the granitic and sandstone areas are clear, and inclusions are not abundant (Plate VI, figs. 1, 3 and 4).

Rutile.

Greywackes. The rare rutile grains are usually rounded, and smaller than those in the beach sands. They are reddish-brown in colour.

Granitic Rocks. The range in colour from yellow-red to black corresponds to that of the beach sand rutile. Most commonly the crystals are deep reddish-brown. Although they are fractured during the mechanical disintegration of the rocks, prism faces are often visible indicating an elongate or stout habit, capped by pyramids.

Sandstones (Plate V, figs. 3 and 4). The rutile grains generally are of a larger size and less abraded nature than those in the beach sands. Some are euhedral or nearly so, and crystals edges usually can be seen. Apparently owing to greater thickness, more grains are of a deeper colour than those in the beach sands.

River Sands. Apart from the larger size and less abraded nature of most of the grains (Plate VI, figs. 3 and 4), the rutile is identical with that in the coastal sands.

Ilmenite.

Greywackes. Many of the grains, unlike those in the beach sands, show partial alteration to leucoxene.

Granitic Rocks. In spite of fracturing from the mechanical disintegration, prism edges often can be seen.

Basalts. Grains fresh and show no alteration to leucoxene. The lustre in reflected light is purple-grey and submetallic.

Sandstones. Usually larger and less abraded than those in the beach sands. Some show alteration to leucoxene.

River Sands. The grains commonly are rather angular, particularly in the samples from regions where Tertiary basalts are abundant (Plate VI, fig. 2). Very few show partial alteration to leucoxene.

Garnet.

Greywackes. The rare grains of this mineral are smaller than from beach sands. They are pink in colour and angular and irregular in shape. Etching of the grain surfaces was not observed.

Granitic Rocks. The variety is almandine, and the colour is pale pink. Although fractured by mechanical disintegration, the dodecahedral habit of the crystals is apparent. Inclusions are scarce.

Sandstones. Usually pale pink in colour, they are the same variety (almandine) as occurs in the beach sands. Most are angular and irregular in shape (Plate V, figs. 3 and 4), like those in the beach sands, but a larger number show crystal edges and evidence of a dodecahedral habit is sometimes seen. In etching and inclusions, they are identical with the beach sand grains of this mineral.

River Sands. A dodecahedral habit is apparent in some, and crystal edges are more often seen than in the beach sand garnet. Etching is seen mainly on those from the sandstones areas (Plate VI, figs. 3 and 4). They are commonly slightly larger than those in the beach sands, but are similar in variety, colour and physical properties.

Tourmaline.

Greywackes. The grains are usually rounded, and some have a high degree of sphericity. Prismatic crystals with the ends only slightly rounded are also present. The most common colour is brown. Although generally larger than the greywacke zircon, the size is smaller than the beach sand tourmaline (Plate V, fig. 1).

Granitic Rocks. The tourmaline usually is brown, although grey, blue and green crystal fragments also occur, sometimes in the same sample. Crystal prism edges are apparent.

Sandstones. The grains are not as rounded as those in the coastal sands, and the short prismatic habit of the crystals is often seen (Plate V, fig. 4). Colour and properties are identical with the beach sand tourmaline.

River Sands. The grains are identical with those in beach sands.

Monazite.

Granitic Rocks. The monazite is honey-yellow in colour, and the stumpy habit of the crystals is apparent. No mineral inclusions were observed, but a few gas-filled cavities and minute dust-like inclusions were seen.

Sandstones. Although most grains are rounded, a greater number show crystal faces and edges than in the beach sands. They are honey-yellow in colour, and often of fairly large size.

River Sands. The monazite is similar to that in the beach sands, apart from larger grain size and less abraded nature (Plate VI, figs. 3 and 4).

Leucoxene.

Greywackes. The grains are dull white in reflected light, and often smaller in size than those in the beach sands.

Granitic Rocks. The very scarce leucoxene may have been derived from the alteration of sphene which is common in sample G, the only sample in which this mineral was found.

Sandstones and River Sands. The grains are similar to those in the beach sands, apart from their slightly larger size and less rounded nature.

Cassiterite.

Greywackes. The rare grains of this mineral are of very small size and are not much rounded. They are particoloured reddish-brown and colourless.

Granitic Rocks. A short bipyramidal tetragonal habit with striations on the crystal faces is apparent. Some are zoned ; colours are ruby and pale grey.

Sandstones and River Sands. The grains are similar to those in the beach sands except for slightly larger size and less abraded nature.

Epidote.

Greywackes. The scarce grains are yellowish-green in colour, and in various stages of alteration. They are faintly pleochroic.

Granitic Rocks. The prismatic habit usually is visible. Some grains are clouded from alteration.

Sandstones and River Sands. The grains are often subhedral and larger than those in the beach sands.

Magnetite.

Granitic Rocks. An octahedral habit is apparent in some, and the material exhibits a silver-grey lustre in reflected light.

Sandstones and River Sands. Octahedral grains are sometimes seen.

Spinel.

Greywackes. The grains are small, green in colour and usually subhedral.

Sandstones and River Sands. Like those in the beach sands, the grains range from bright green to dark greenish-black in colour. Apparently many are chrome spinel. They are slightly larger than those in the beach sands ; some show octahedral habit.

Augite.

Basalts. The augite is usually the violet-tinted titaniferous variety, but some grains are colourless or faintly green. Prism faces are usually visible and inclusions of iron-ore are not uncommon.

River Sands. The grains are very small, and are prismatic with rounded ends. Cleavage can be seen.

Sphene.

Granitic Rocks. The sphene is brown in colour, and shows evidence of a diamond or wedge-shaped habit. During the mechanical disintegration, fracturing has occurred, and irregularly shaped, ragged particles have been produced. They have a vitreous lustre and somewhat watery appearance. Refractive index is particularly high, and there is a total absence of extinction.

Sandstones and River Sands. The grains are usually fresher than those in the beach sands, as well as being larger and less abraded.

Apatite.

Granitic Rocks. The prismatic crystals are colourless and clear to brownish. Some show evidence of corrosion (probably magmatic). Inclusions are rare, and so minute that they are indeterminable.

Sandstones and River Sands. The sparse grains are rounded and very small.

Topaz.

Granitic Rocks. The topaz is colourless and glassy in appearance. Fractured surfaces sometimes have a pale bluish tinge. Cleavage is visible.

Sandstones and River Sands. The sparse grains are colourless and rounded. They yield good biaxial, positive interference figures.

Anatase.

Greywackes. The grains are bluish, square and tabular, and show no signs of wear. They are probably authigenic and derived *in situ* from the decomposition of the ilmenite.

Granitic Rocks. The sparse anatase is yellow and indigo-blue in colour, and the crystals have octahedral and square, tabular habits. Some show zoning or geometric patterning. There is good cleavage. Pleochroism is faint but distinct.

Sandstones. The occurrence of perfect crystals showing square, tabular habit suggests that this mineral is authigenic.

Kyanite.

Greywackes. The grains are colourless. They are usually elongated and show prism edges, with rounded ends. There is good cleavage. Inclusions are rather common.

IX. CONCLUSIONS AND OUTLINE OF GEOLOGICAL HISTORY OF THE HEAVY MINERALS.

For the first time, mechanical analyses of panned heavy mineral concentrates and statistical measures derived from their cumulative frequency curves have been used to compare and describe the physical composition of beach sand concentrates. This has been possible because the particular concentrates are made up almost entirely of minerals which have similar specific gravities, and have been concentrated in grains of very similar size.

Statistical measures, particularly the median diameter and Trask's coefficient of sorting, have been found to be very useful in the work on the mechanical composition of the concentrates. By plotting the median diameter and the coefficients of sorting and skewness against the geographic distance along the coast, changes in these values can clearly be seen, trends observed, and suggestions concerning their relation to heavy mineral supply and direction of transport have been made possible. From the abrupt increases in median diameter and coefficients of sorting around the major coastline breaks and about the headlands of Mesozoic sandstone, it is suggested that heavy mineral material has been added to the shore at these points. This view is supported by the decrease in the degree of mineral abrasion at these places.

The heavy minerals are well sorted but, contrary to common belief, the highest degree of sorting is not present in the dune sand concentrates.

Over 90% by weight of the heavy minerals in all the coastal sand samples is made up of zircon, rutile and ilmenite. Of the other minerals, garnet, tourmaline, monazite and leucoxene are the more common. The concentrates are distinguished from those in other parts of the world by the high zircon and rutile content.

The most striking feature in distribution is a decrease in zircon and increase in ilmenite content from south to north as far as the South Passage. Northwards from the South Passage the percentages of zircon, rutile and ilmenite remain more or less constant. The heavy mineral analyses of the samples from localities south of the South Passage, in which there is a higher zircon and rutile content, combined with the results of the writer's field survey, clearly indicate that the deposits in that region are of greater economic value than those to the north.

For the enquiry into the source of the heavy minerals, study of increases and decreases in content of the various minerals, presence and absence of certain species, mineral appearance, grain size, and degree of abrasion, have been found useful. It is concluded that the Mesozoic sandstones of the region are the source of most of the heavy minerals in the coastal sand deposits, but that at least some of the ilmenite has been derived from the Tertiary basalts. The fact that the beach sand ilmenite throughout the area usually is less abraded than the zircon and rutile, in spite of its softer nature, supports the view that the detrital history of this mineral generally has been shorter than that of the zircon and rutile.

Although the sandstones are the immediate source rocks of most of the heavy minerals, they are a secondary source. As they are of Upper Triassic and Jurassic age, the primary source or sources of the heavy minerals must be rocks of an earlier period. The heavy minerals of the coastal sands suggest an igneous source, not metamorphic. Such metamorphic minerals as kyanite and staurolite are almost absent from the sands, although they are comparatively stable heavy minerals and are abundant in beach deposits in other parts of the world. Many of the species in the beach sands indicate an acid plutonic source. The only rocks of this type of pre-Upper Triassic age in the region investigated, as well as to the south, west and north, are the Permian "granites." It is concluded that these granitic rocks are the primary source of most of the heavy minerals. The pegmatites, greisens, and other marginal products of the granitic bodies, including some rutile and tin lode deposits, are believed to be of particular importance as source rocks.

Following the uplift and earth movements at the close of the Palaeozoic, the Permian granitic masses were soon unroofed, and with weathering, there began the first cycle of erosion, transportation, and deposition of most of the heavy minerals of the coastal sand deposits. There was a large amount of erosion before the Jurassic. The marginal parts of the granitic bodies would be first exposed to weathering, and as these parts were rich in heavy accessory minerals, the swiftly flowing streams draining the rejuvenated area would bring a large amount of heavy minerals into the Mesozoic freshwater lakes. During this first cycle of erosion, some of the less stable minerals would be removed, and a greater concentration of more stable heavy minerals effected.

Since the draining of the lakes almost all the region has been dry land. Much of the freshwater Mesozoic sandstones are soft and easily eroded, and with weathering and disintegration, there began the second cycle of erosion, transportation, and deposition of most of the heavy minerals of the coastal sand deposits. The minerals were carried towards the Pacific Ocean by coastal streams which were fast flowing, particularly after the movements of uplift and consequent rejuvenation in Cainozoic times. Also during this cycle a greater concentration of hard and chemically resistant heavy minerals was effected by the removal of the less stable species. The minerals generally became more abraded, and the grain size finer.

Although there were outpourings of basic lava in Pliocene times over large parts of the area, the main coastal streams are believed to have existed in approximately their present positions before that time. Following the major uplift at the close of the Tertiary, erosion was particularly active and much detritus from the basalts was transported seawards by the streams, and a much greater concentration of ilmenite was effected than of the less stable augite and apatite. In addition to the material brought down by the coastal streams, direct erosion of the headlands of Mesozoic sandstone and Tertiary basalt along the coast has supplied heavy detrital minerals to the shore. The higher ilmenite content of the beach sand concentrates in the northern part of the region is due to the greater amount of ilmenite brought down by the coastal streams in that part. Most of this is believed to have come from the Tertiary basalts, as the Mesozoic sandstones examined from the northern areas do not have an ilmenite content appreciably greater than those in the south.

During periods of coastal subsidence in Quaternary times the beach and adjacent dune sands were passed through the surf zone. Also, there must have been in the past, as at present, some direct erosion of the sand deposits adjacent to the beach by high storm waves.

Although the heavy minerals are being brought down by coastal streams at the present day, particularly during floods, most of the heavy minerals in the coastal sand deposits reached the sea in pre-Recent times. They have been moved northwards along the coast by beach and longshore drift, but they have not been carried very great distances. Storm-wave and strong wind action have concentrated deposits, in some cases of very considerable size and economic value.

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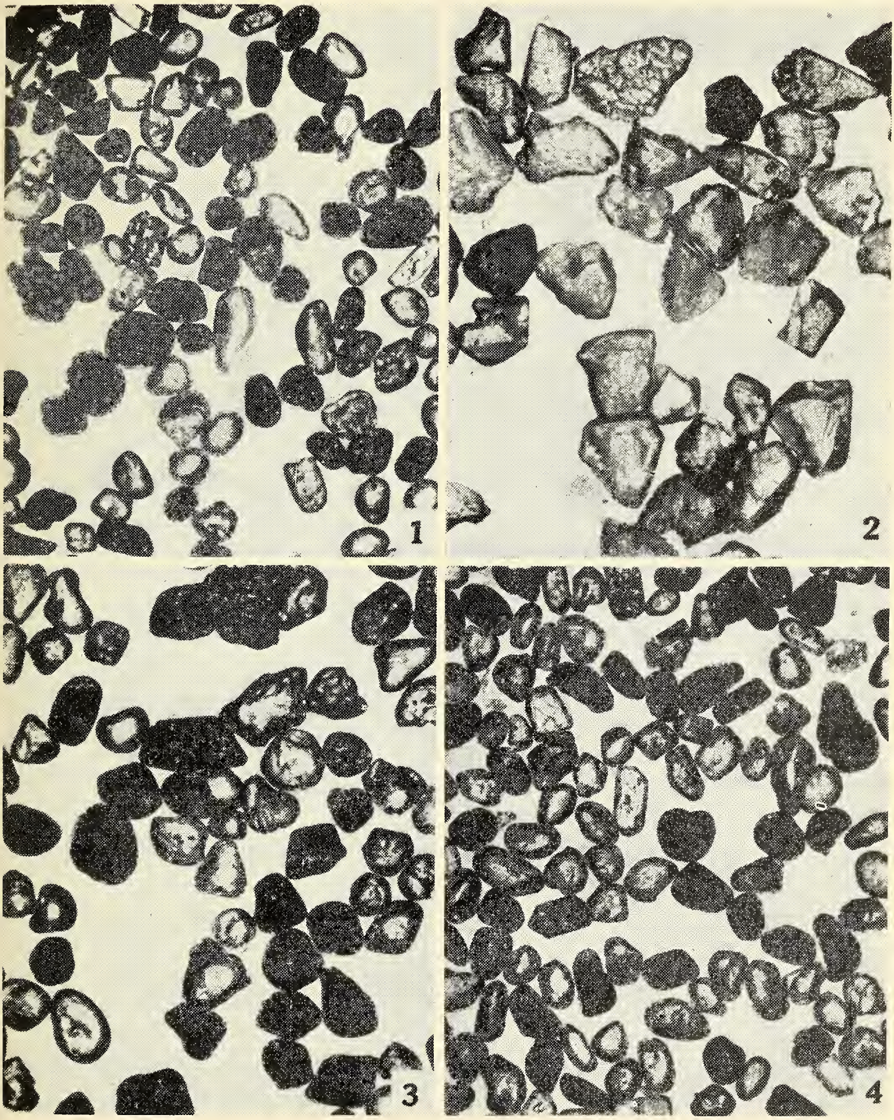

PLATE I.—Heavy Mineral Beach Sand ; Sample No. 7 (Tugun) x 35.

FIG. 1 : Bromoform-separated heavies. The rutile and iron-ore minerals appear black in the photograph. FIG. 2 : Garnet fraction. Note large size, angularity, and etched surface of grains. FIG. 3 : B.S.S. + 120 size fraction, after extraction of highly magnetic and moderately magnetic minerals. FIG. 4 : B.S.S. — 120 size fraction, after extraction of highly magnetic and moderately magnetic minerals.

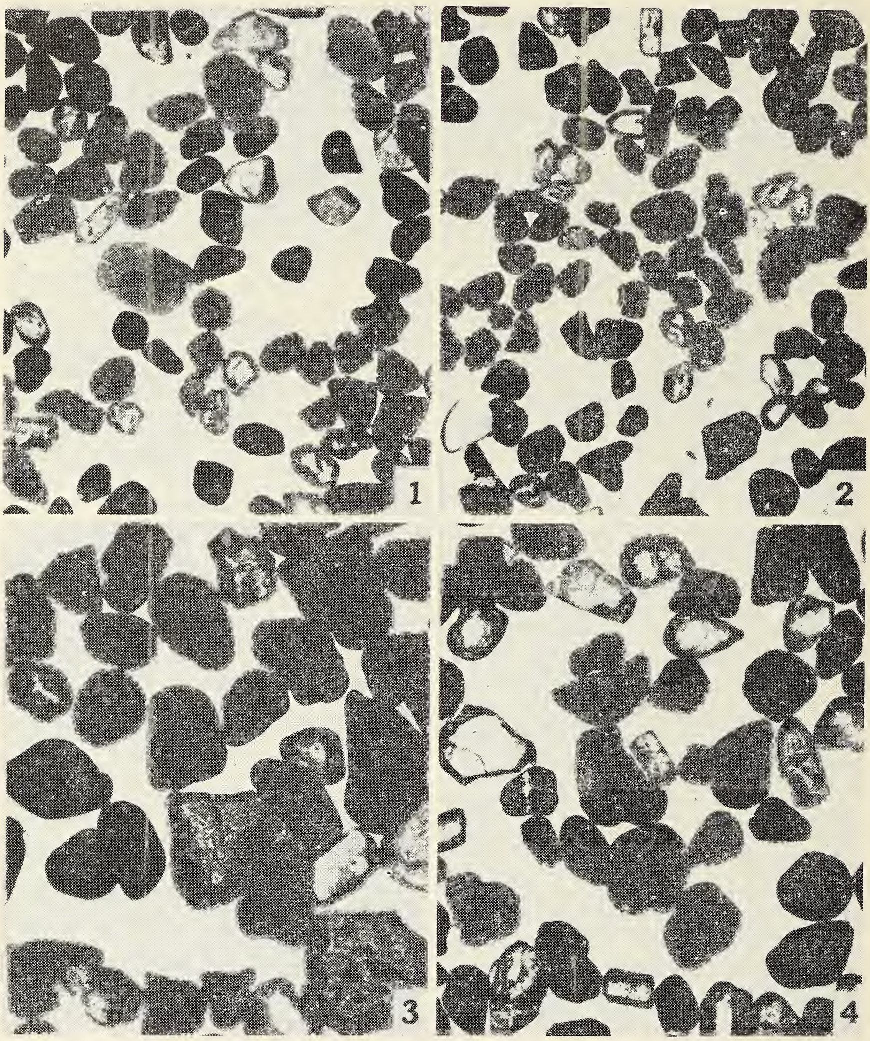

Plate II.—Bromoform-separated Heavy Mineral Sands x 35.

Fig. 1 : Beach on North Stradbroke Island ; sample No. 21. Note two large, translucent grains of tourmaline. Fig. 2 : Dunes on North Stradbroke Island ; sample No. 27. Note great number of black grains ; also tourmaline grain showing one prism-edge near lower left-hand corner. Fig. 3 : Beach at Caloundra Head ; sample No. 39. Note large size of grains, especially of garnet, in this concentrate from near sandstone headland. Fig. 4 : Beach at Point Arkwright ; sample No. 41. Same comments as for Fig. 3 apply. Note three grains of garnet towards left, and the large, subhedral grain of monazite at right of centre.

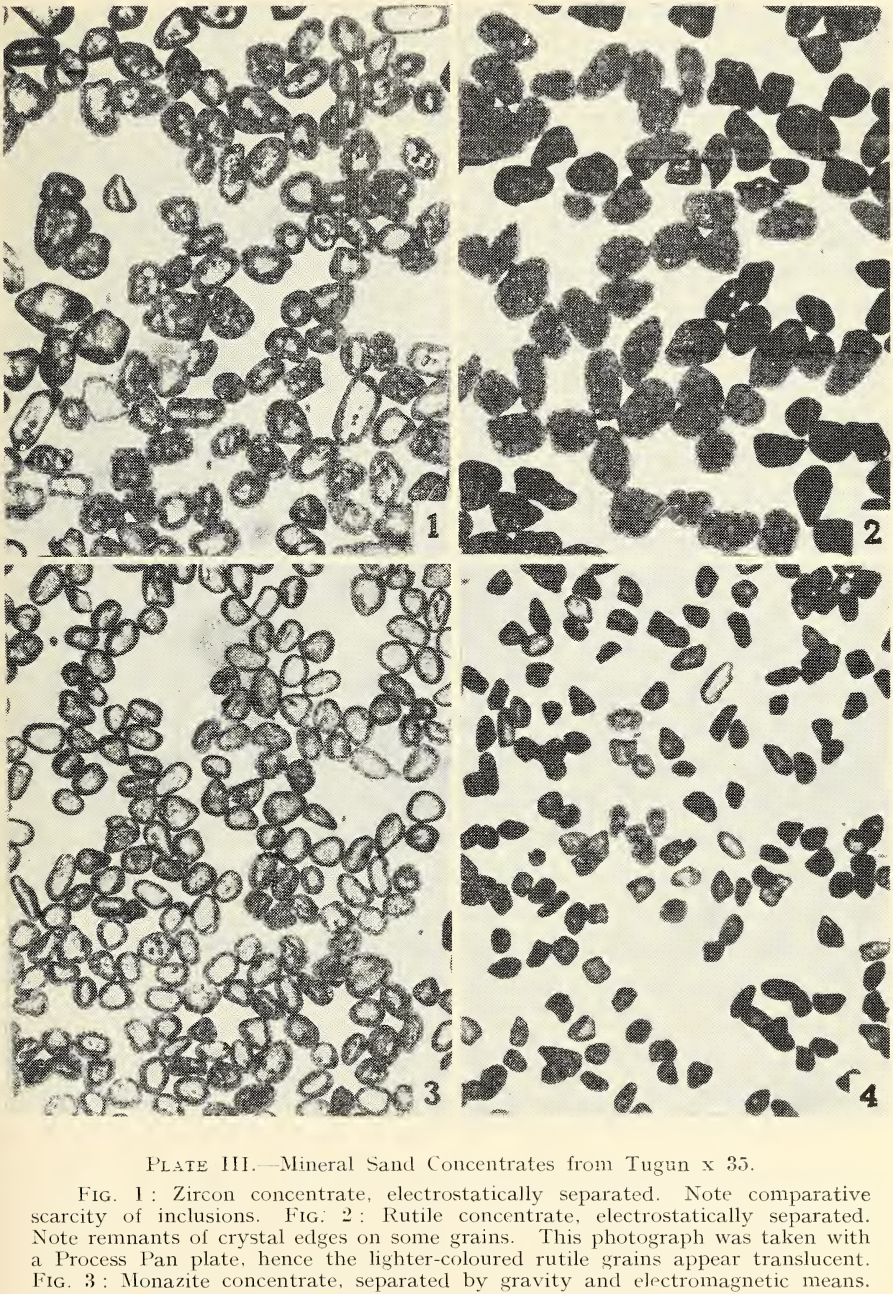

PLATE III.—Mineral Sand Concentrates from Tugun x 35.

FIG. 1: Zircon concentrate, electrostatically separated. Note comparative scarcity of inclusions. FIG. 2: Rutile concentrate, electrostatically separated. Note remnants of crystal edges on some grains. This photograph was taken with a Process Pan plate, hence the lighter-coloured rutile grains appear translucent. FIG. 3: Monazite concentrate, separated by gravity and electromagnetic means. FIG. 4: Cassiterite sand concentrate, separated by gravity.

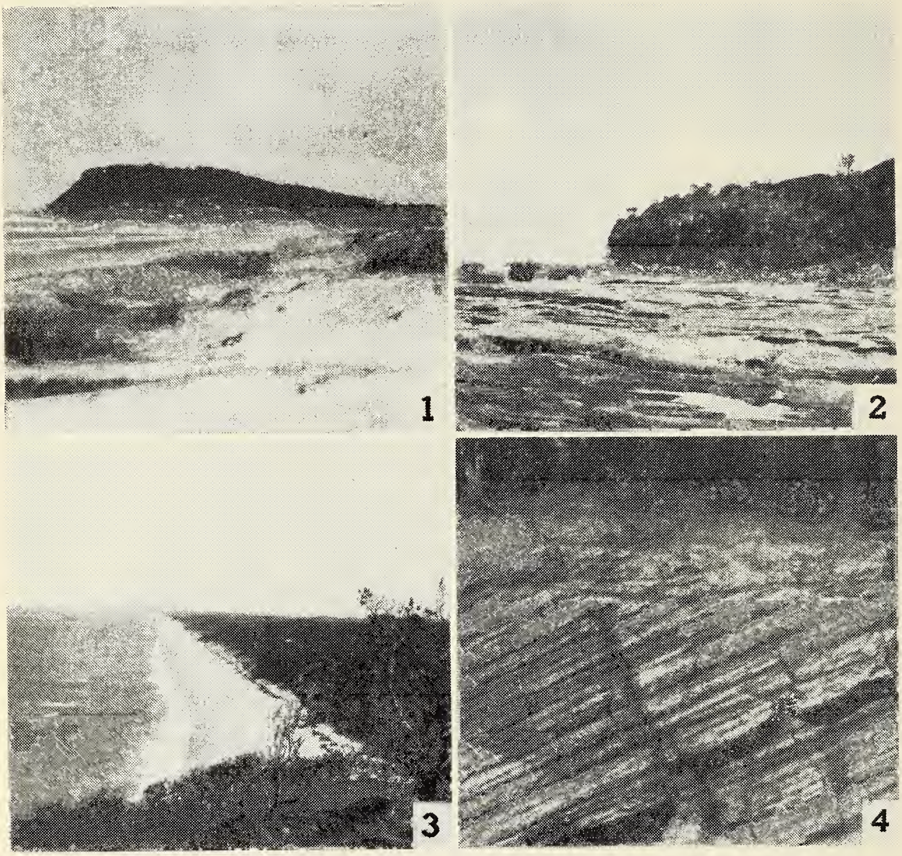

PLATE IV.

FIG. 1: Burleigh Head, S.E. Queensland; made up of Lower Palaeozoic greywacke overlain by Tertiary basalt. FIG. 2: Upper Triassic Bundamba sandstone outcropping at Caloundra Head. FIG. 3: Looking south from Paradise Caves (Noosa Head) along Coolum Beach. Point Arkwright in the distance. FIG. 4: Freshwater Jurassic sandstone, showing current bedding, at Noosa Head.

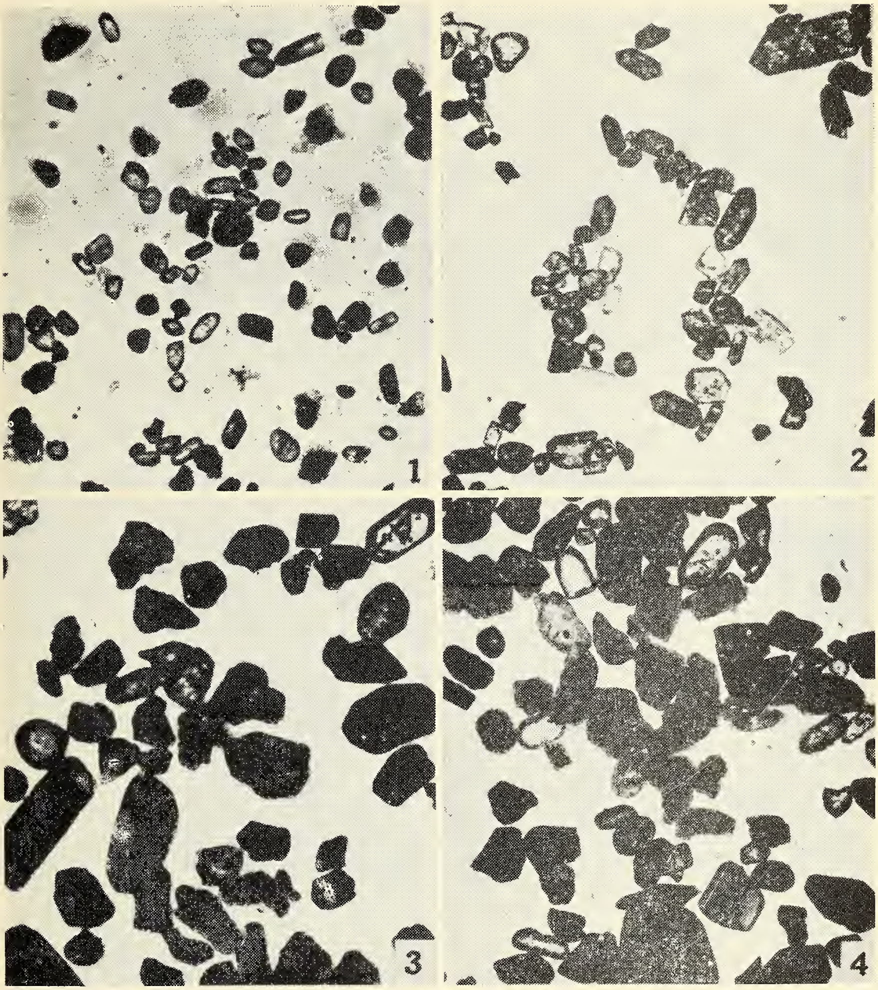

PLATE V.—Bromoform-separated Heavy Mineral Fractions x 35.

FIG. 1 : From Burleigh Head greywacke ; sample A. Note small size of grains cloudy appearance of zircon, and prismatic habit of some of the tourmaline grains. FIG. 2 : Non-magnetic heavies from Tenterfield granite ; sample D. Note high zircon content, and prismatic apatite and rutile fragments (black in photograph). FIG. 3 : From Clarence Series sandstone ; sample N. Note the larger size of most of the grains, their less abraded nature, and the poorer degree of sorting, as compared with most of the beach sand concentrates. The long, prismatic grain near the left-hand edge is rutile. FIG. 4 : From Jurassic sandstone at Point Arkwright ; sample T. Note similarity in grain size with Point Arkwright beach sand concentrate (Plate II, fig. 4), and lower degree of abrasion and sorting. A subhedral grain of tourmaline is in lower part of photograph.

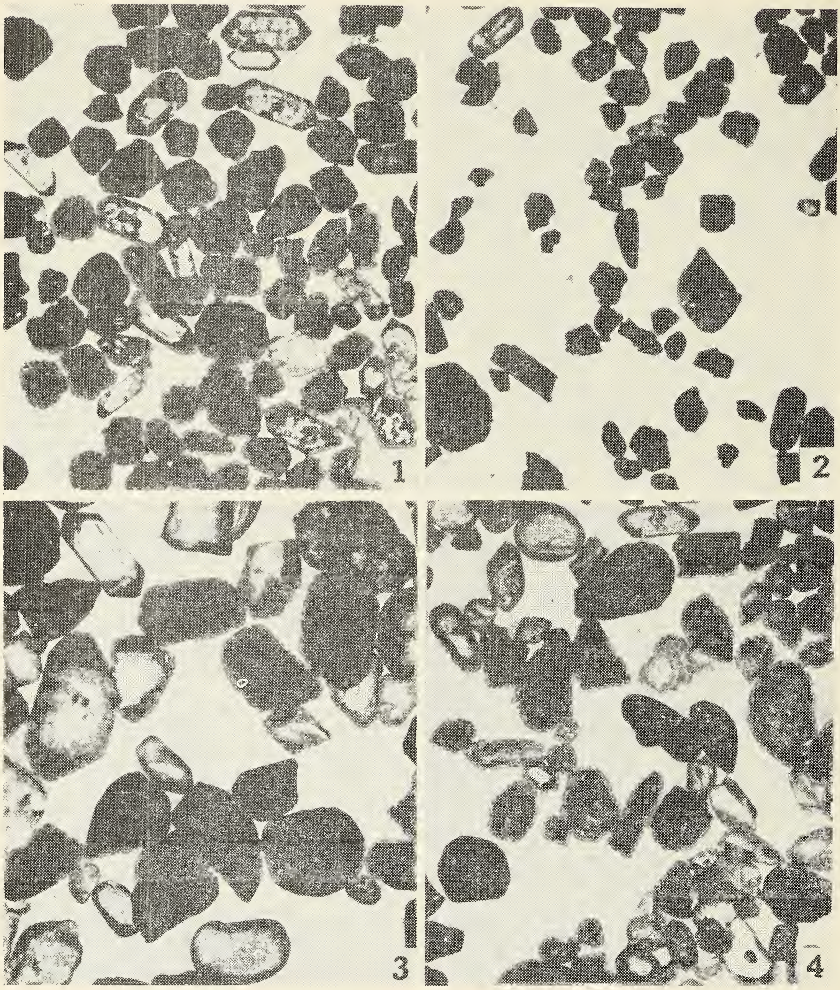

PLATE VI.—Heavy Mineral Fractions from River Sands x 35.

FIG. 1 : In New England granitic area ; sample W. Note high content of zircon and iron-ore minerals, and small degree of abrasion. Compare size of zircon with Plate III, fig. 1. FIG. 2 : From Currumbin Creek ; sample ZC. Almost all the black grains are ilmenite. Note very low degree of abrasion. FIG. 3 : From Oraro River, which flows entirely through Clarence Series sediments ; sample U. Note larger size, and less abraded and less well-sorted nature of the grains than in most of the beach sands. A large, bean-shaped grain of monazite is at the lower margin of photograph. FIG. 4 : From tributary of Richmond River ; sample Z. As in Fig. 3 note large size of monazite and other mineral grains, and greater number of euhedral and subhedral zircon grains.

FREDERICK MANSON BAILEY

MEMORIAL ADDRESS:

F. M. BAILEY: HIS LIFE AND WORK

By C. T. White, Government Botanist.

(*Delivered before the Royal Society of Queensland, 28th November,* 1949; *issued separately* ————).

Frederick Manson Bailey, the most outstanding member of a line of botanists and horticulturists, was born at Hackney, England, on the 8th March, 1827, and died at Brisbane on the 25th June, 1915. His father, John Bailey, had been with Conrad Loddiges and Sons, the famous nurserymen of Hackney, England, in the early part of the nineteenth century. At that time, great interest was taken by British gardeners in the new and intriguing flora of South Africa, on the one hand, and Australia on the other. South Africa gave to the horticultural world the " Cape-bulbs " which included numerous species of *Gladiolus, Watsonia, Ixia, Sparaxis* and others which have been hybridised and remained firm favourites in all parts of the world where they can be grown. The South African heaths were another group introduced into general culture about that time.

Australian plants for the most part require the protection of a cool or temperate house in Britain, but became firm favourites, especially the Acacias or wattles, Boronias, Leptospermums and other Myrtaceae and the shrubby Proteaceae. The first half of the nineteenth century was an active era in the publication of works with coloured plates of plants and those of New Holland, as Australia was then most generally known, claimed considerable attention.

In 1787, Wm. Curtis started the *Botanical Magazine*, a work still regularly appearing and edited at the Royal Botanic Gardens, Kew (Eng.), for the Royal Horticultural Society. The early volumes, like those of the present day, contain numerous illustrations of Australian plants. A few years later (1791) the first volume of H. C. Andrew's *Botanist's Repository* appeared; this work ran to 10 volumes, the last appearing in 1849. Another important series was the *Botanical Register*, commenced in 1815 and discontinued in 1847. It contained, especially from Vol. XV onwards, when John Lindley assumed the editorship, numerous coloured illustrations of Australian plants, particularly those of the "Swan River Colony" (Western Australia). A more popular series stressing methods of cultivation was Paxton's *Magazine of Botany*, 16 volumes, 1836-1849.

Two important works with coloured illustrations were J. E. Smith's *A Specimen of the Botany of New Holland*, published as early as 1793, and R. Sweet's *Flora Australasica* in 1827-28. In France in the years 1803-4 appeared Ventenat's *Jardin de la Malmaison*, with very large coloured plates, in which some Australian plants were described and figured for the first time.

Conrad Loddiges and Sons was a firm of botanical nurserymen who helped to introduce and popularise plants from abroad, especially South Africa and Australia. In addition to being expert nurserymen, the Loddiges were good botanists and published a notable work, *The Botanical Cabinet*. This work, which is still regularly quoted in botanical literature, consists of 20 volumes ; the first appeared in 1817, the last in 1833. Each volume consists of 100 plates partly in colour ; thus 2,000 exotic plants were figured, many for the first time. It was natural therefore that a member of such a firm should be chosen by Governor Gawler as Government Botanist and Curator of a Botanic Garden which it was proposed to establish in the young colony of South Australia. For this, John Bailey was to receive the magnificent salary of £80 per annum With his family—wife, two sons, one of whom was Frederick Manson, and I think a daughter—he left England on the 12th December, 1838, in the frigate "Buckinghamshire" which cast anchor in Holdfast Bay, South Australia, just 100 days later, 22nd March, 1839. She was the largest vessel to visit Australia up to that time, her gross burthen being 1500 tons, and she made an exceptionally fast passage.

A botanic gardens was laid out on the banks of the Torrens River. It was divided into two sections, one devoted to flower-beds and ornamental plants, the other to an economic section. One important function of the latter was the growing of fresh vegetables to combat scurvy. I do not know when this Botanic Gardens was abandoned, but it was probably towards the end of 1841 when drastic cuts in administration costs were made by Grey in an endeavour to pull the colony out of bankruptcy. No money being available to carry on the Botanic Gardens, John Bailey turned his hand to farming and later to nursery work, establishing the Hackney Nursery, after which the present suburb of Adelaide is named. In this venture his two sons were associated with him under the name of John Bailey & Sons.

The early Botanic Gardens had no connection with the present one in Adelaide, which was not established until 1855. F. M. Bailey was somewhat annoyed, that in any subsequent history of South Australia, 1855 was given as the date of the foundation of the Botanic Gardens and the earlier one ignored. The early Gardens, however, from what I gathered from him in conversation, were largely devoted to the growing of flowers, vegetables and field crops. An important part of the work was the introduction of economic plants. One of the most important of these was the true Zante currant. Life in the colony was hard in the early forties. Wheaten flour was very expensive and Mrs. Bailey used the grain of one of the Sorghums for the making of johnny cakes and dampers. The grain was ground in the family coffee-grinder. The skinless barley, according to the younger son, F. Manson Bailey, in one of his reminiscences, was experimented with but had to be given up, not only for fear of damaging the mill, but because the noise startled the natives in their wurlies ! Lighting oil also was scarce, and frequently the younger members were sent out to collect large heaps of small bark strips with which they constantly fed the open fire so that the older ones could read by the light given out by the blaze. Young Fred Bailey had just turned 12 when the family arrived in South Australia, so that it is only natural that—apart from an early schooling at the Foundation School of the Independent Church at Hackney, England—he was largely a self-taught man. He was an omnivorous reader and part of his reading was done when ploughing ; this was made possible by the fact that slow-moving bullocks instead of horses were used for this work. Partly influenced by family reasons, and partly by the lure of the goldfields being opened up in the fifties, F. M. Bailey (now a young man in the twenties) decided to dissolve the partnership with his father and brother and engage in mining. He had hardly time to try his luck, however, before he was recalled to Adelaide by the illness of his father. He resumed his position in the business, but in 1858 resolved to go forth on a fresh quest to New Zealand, where he took up land in the Hutt Valley. Soon afterwards he decided to return to Australia. After a brief stay in Sydney, he came to Brisbane in 1861 and was destined to play a most important part in the scientific life of the new State where, except for brief visits to the other States, New Zealand, and New Guinea, he was not to leave again during his long life.

Soon after landing in Brisbane he opened a seed store in Edward Street, and in addition he collected botanical specimens for sale to British and foreign Botanical Museums and Herbaria. Partly owing to times of financial stress in the colony, and probably to a lack of business acumen, the store was closed and he had to look elsewhere for a means of support for himself and his family, by this time totalling six children (three sets of twins).

Official Life.

In 1875 the Government set up a board to enquire into the causes of the disease of livestock and plants in Queensland and F. M. Bailey was appointed botanist. On this cause he travelled extensively in the State, especially in connection with plants reputed poisonous to livestock on the one hand and with grasses and native pasture herbage on the other.

In December, 1880, on the recommendation of his very close friend, the Rev. J. E. Tenison-Woods, S.J., he was appointed Acting Curator of the Queensland Museum, a position he held until March, 1882, when a permanent Curator (Mr. C. W. De Vis) was appointed. The Report of the Trustees of the Queensland Museum for the year 1881-82 contains the following reference :—

> " From December, 1880, until March, 1882, Mr. F. M. Bailey performed the duties of Curator, carrying out the general management of the Museum together with his own botanical work, in a manner highly satisfactory to the Trustees ; and, by his efforts, the phytological specimens in the upper story had been put in order.
>
> During the last year the extensive botanical library, previously kept in the Curator's cottage at the Botanic Gardens, has been transferred to the large room in the basement floor of the Museum building, where Mr. Bailey now works as Government Botanist. In this room are also contained the few works of reference belonging to the Museum and the varied library of the Philosophical Society."

In 1881, while still Acting Curator of the Museum, he was appointed Colonial Botanist, a position he held until his death. He retained quarters at the Queensland Museum until 1889, when the Department of Agriculture, under whose auspices he worked, was transferred to a building of its own in William Street. He stayed there until 1912, the Museum of Economic Botany and the Herbarium occupying three large rooms, one of which is the present Ministerial office. In 1912 the Museum and Herbarium were transferred to a special building in the Botanic Gardens, which was then a Government activity under the control of the Department of Agriculture and Stock. On the inauguration of the Greater Brisbane Scheme in 1925 the control of the Botanic Gardens was transferred to the Brisbane City Council.

Bailey never received a high salary ; for many years he received £300 per annum, and I do not think this was ever exceeded. It was intended to retire him from the Public Service in 1902, but he said he could not accept retirement and would go on working as far as he could without pay, and that if the authorities wished to retire him they would have to carry him out into the street. After some publicity had been given to the matter in the press and his work for the State publicly praised, his services were retained but only on half-pay, £150 per annum, and later, a few years before his death, this was raised to £200 per annum.

Journeys and Collections.

He was an ardent collector, and specimens of his gathering are well represented in the Queensland Herbarium, while earlier ones especially are in various herbaria abroad. For some years after his arrival in 1861 he collected assiduously about Brisbane. He was especially interested in cryptogams, although apart from the pteridophytes he did little or no work on these groups himself, but he corresponded and sent specimens to various specialists as follows :—

Fresh-water algae :—E. Askenasy, W. Schmidle and later M. Moebuis and Otto Nordstedt. (Three of the Botany Bulletins (Nos. V, VI and XI) issued by the Department of Agriculture, Brisbane, dealt with these plants.)

Marine algae (seaweeds) :—These were not collected by Bailey in his early days in Queensland, and it was not until a few years before his death that he started sending them to A. D. Cotton (Kew).

Characeae :—O. Nordstedt, and much later to H. & J. Groves (London).

Fungi :—M. J. Berkley, later to M. C. Cooke, and then to George Massee (Kew) ; in later years a few were determined by Miss E. N. Wakefield (Kew). One of the earliest papers on Australian Fungi was "*List of Fungi from Brisbane, Queensland, with Descriptions of New Species*," by M. J. Berkley and C. E. Browne. Based largely on F. M. Bailey's collections, it was read before the Linnean Society of London on 23rd March, 1878, and published in the following year in the Society's Transactions.

Lichens :—J. Mueller, later to Chas. Knight and J. Stirton.

Mosses :—V. J. Brotherus.

Liverworts :—F. Stephani.

Duplicates of most of these collections are in the Queensland Herbarium though not all, because for some reason he always regarded these as his private property and they were not incorporated in the official collections until after his death. I am also afraid that the collections have been neglected for many years, largely due to the absence in Queensland of specialists in most of these groups. Apart from local botanising, his most extensive collecting trips as far as I can gather were as follows :—

1873 : Rockingham Bay, Upper Herbert River, and Seaview Range, North Queensland.

1876 : Warrego, Maranoa and Leichhardt Districts, Western Queensland. He apparently travelled to Roma, thence to Morven, Augathella, Tambo, and on to Rockhampton.

1877 : Cairns and ranges about the Barron River, North Queensland.

1886-1894 : The Field Naturalists' section of this Society was formed in 1886 and started with fortnightly excursions. From the beginning, F. M. Bailey was one of the most active members of the section. The years 1891-4 were particularly active botanically, as the members of the section followed the Brisbane-Gympie railway line as it was being built and collected extensively in the then rich rain-forests from Eudlo to Cooroy. Many new species of plants were described by Bailey from this region. The section, however, gradually dwindled until only three or four members remained. The last report was one by F. M. Bailey on some plants from Eumundi to Cooroy, read before this Society on 21st April, 1894, and published in Vol. X of its Proceedings (pp. 51-53).

1889 : Bellenden Ker Expedition (North Queensland). He always regarded this as his main collecting trip. The results certainly added considerably to a knowledge of the flora of tropical Australia. They were published, including descriptions of new species, in the *Report of the Government Scientific Expedition to Bellenden Ker Range*, which was issued in two forms : (1) foolscap size as a Parliamentary Paper, and (2) as a special publication in demy 8vo size of the Department of Agriculture and Stock, Brisbane. Both bear the date 1889 on the title page, but it is probable that the first has priority. It is extremely rare, however, even in Australian libraries, whereas the latter is moderately common and was the one always quoted by Bailey himself and by subsequent authorities. He republished several of the new species in other publications, especially the third supplement to the *Synopsis of the Queensland Flora*, and frequently gave this as the place of publication with or without reference to the Report.

1895 : Georgina River, Western Queensland. This visit was made especially to investigate the course of the so-called Georgina River disease in cattle, thought to be due to a plant. He blamed *Eremophila bignoniiflora* as the possible cause of the trouble. We now know this to be one of the best of the inland fodder shrubs and trees, and recent investigations lay the blame on a member of the same genus, *E. latrobei*.

1897 : Torres Straits. Early in the following year, 7th January, 1898, he read a paper entitled *A Few Notes on the Flora of the Islands of Torres Straits and the Mainland about Somerset* at the Sydney Meeting of the Australasian Association for the Advancement of Science. This was published in Vol. VII of the Association's *Proceedings*.

1898 : British New Guinea. At that time the territory was governed from Brisbane and F. M. Bailey accompanied Lord Lamington on a tour of inspection. Facilities for collecting were poor and Bailey suffered considerably from fever during the trip. The botanical results were in consequence rather meagre, and the specimens collected for the most part very poor. A complete list, without any descriptions of the plants collected, was given under the title *Names of easily Recognised Plants observed by Lord Lamington's Party during New Guinea Expedition* as an appendix to a Parliamentary Paper, *Report of Visit to New Guinea*, Brisbane, 1898. Descriptions of the new species appeared in three small papers in the Queensland Agricultural Journal for September, October and November, 1898.

In some ways he was not unlike his more famous contemporary Ferdinand Mueller, in as much as he described many of his finds direct in the field. As far as I could gather from conversation with him and an examination of his field notebooks, he apparently sometimes sat down on a log or in camp and described his specimens, at least those he thought previously undescribed, in sufficient detail to use the field MS. without alteration for his reports and publications. I should say it is doubtful if many of these specimens were checked over with previous collections, floras or monographs. Both he and Mueller had the habit at times of naming new species from mere fragments ; for instance, Mueller named *Flindersia papuana* from an immature fruit and *Bassia maclayana* from a single seed, and Bailey named *Myrtus metrosideros* from leaves only. Though both founded institutions that have become centres of research in systematic botany, I doubt if either took a great deal of interest in herbaria as such. Probably neither realised the importance of type-collections or of full details on herbarium sheets, for in both the National Herbarium at Melbourne and the Queensland Herbarium, Brisbane, there are numerous specimens lacking collector's names, and dates and localities are often abbreviated. Both Mueller and Bailey relied on their own knowledge of handwriting and general "look" of a specimen to tell the collector's name. Both had the habit of drawing up descriptions of new species from composite collections, but in this and other points mentioned they were to a large extent characteristic of their time. Even in the largest herbaria of those days, the collectors represented were comparatively few and curators relied on their personal knowledge to associate the specimens in their charge with collector and locality.

What I have read of Baron Mueller's life and my personal contact with F. M. Bailey lead me to the conclusion that both thought they had "cleared up" the flora of Australia in general and Queensland in particular respectively, leaving only a few crumbs for those who came after. As a matter of fact, genus after genus of Australian plants is literally "crying out" for revisional work in the light of modern knowledge, and it will require many years and a host of workers before this work is anything like complete.

Publications.

F. M. Bailey was a prolific writer, and from the date of his appointment as Colonial Botanist in 1881 until his death in 1915, scarcely a day passed without some manuscript, however short, being prepared for publication. He always had a particular liking for the ferns and their allies, the lycopods, and before his official appointment had published privately as early as 1874 his *Queensland Ferns*, a book of 70 pages and 63 small illustrations distributed over 23 plates at the end of the work ; these latter were made by his friend Mr. H. S. Eaton, a well known local artist of the time.

While botanist to the Board set up by the Government to enquire into the causes of diseases in live-stock in Queensland he published in 1878, in association with K. T. Staiger, then Government Analyst, Vol. I of an *Illustrated Monograph of the Grasses of Queensland ;* 42 grasses were described by Bailey and each species illustrated by electrotype nature-printing by Staiger. This work is now very rare, and no subsequent volumes were issued.

Before his appointment as Colonial Botanist he had prepared his only work dealing with Australia as a whole. This was the *Fern World of Australia*, published by Gordon and Gotch in 1881. It contains 106 pages and two plates, one illustrating the tribes of ferns as then understood, the other the four genera of lycopods. It is not surprising that he dealt with the ferns of Australia as a whole, including Lord Howe Island, for of the 245 species dealt with, only 30 are not found in Queensland although many are common to Queensland and the other States, particularly northern New South Wales. He contributed several papers of a general nature, such as some on Queensland fungi, medicinal plants and introduced plants, to the early volumes of the *Proceedings of the Linnean Society of New South Wales.* The most important was a *Census of the Flora of Brisbane* (in conjunction with the Rev. J. E. Tenison-Woods), read before this Society on 20th March, 1879, and published in Vol. IV of its Proceedings. From the date of his appointment as Colonial Botanist all his papers (with a very few exceptions in the Proceedings of this and other Australian Societies) appeared in official bulletins or journals of the Department of Agriculture (later Department of Agriculture and Stock), or as special publications of that Department. One exception was the *Weeds and Suspected Poisonous Plants of Queensland,* which appeared in 1905-6, and is specially mentioned below. A list in chronological order (with notes) of his main works follows :—

1874—*Queensland Ferns.*

1878—*An Illustrated Monograph of the Grasses of Queensland* Vol. 1 (in conjunction with K. T. Staiger). No other volumes were issued.

1881—*Fern World of Australia.*

1883—*A Synopsis of the Flora of Queensland.* Three supplements were subsequently issued in 1886, 1888 and 1890 respectively. An appendix to the synopsis that was also issued separately was *A Classified Index of the Indigenous and Naturalised Plants of Queensland.* With the additional supplements, fresh classified lists were issued as separate publications and called *Catalogue of the Indigenous and Naturalised Plants of Queensland.*

1885—*Catalogue of Plants in the Two Metropolitan Gardens, The Brisbane Botanic Gardens and Bowen Park.* This is more than a mere list as it gives native countries and notes on properties. It is still a very useful guide to the ornamental plants grown in Queensland.

1886, 1888, 1899—*Catalogue of Queensland Woods* (Three editions). F. M. Bailey was very active in getting together for display purposes collections of woods, grasses and economic plants for important exhibitions. These were accompanied by descriptive catalogues. The most important are those describing the timbers. Catalogues were compiled for the following exhibitions : Colonial and Indian Exhibition, London, 1886 ; Centennial International Exhibition, Melbourne, 1888 ; and Greater Britain Exhibition, London, 1899. The catalogues were issued separately in booklet form.

1887—*Plants Reputed Poisonous to Live Stock in Queensland* (in conjunction with P. R. Gordon). This is a book of 112 pages and 45 full-page plates from excellent pencil drawings by Miss M. A. Hope.

1890-1913—*Botany Bulletins* (*Department of Agriculture, Brisbane*), 1-17. The first three bear only numbers of the general bulletin series of the Department and are numbered Bulletins 4, 7 and 9 respectively. The only indication that Nos. 7 and 9 are the second and third of the botanical series respectively is in the prefatory notes. The next four were entitled Bulletins 13, 18, 20 and 21, but in addition bore the sub-titles of *Botany Bulletin* Nos. IV, V, VI and VII respectively. From then they were simply entitled *Botany Bulletin* VIII and so on to XVII. The series was continued by subsequent Government Botanists, but ceased with No. XXII (1920).

1891—*Official Guide to the Museum of Economic Botany, Department of Agriculture, Brisbane.*

1892—*Lithograms of the Ferns of Queensland.* This work consists of 191 plates of nature-prints direct from the stone ; in the case of some of the smaller species more than one appears on a page. No letter-press accompanied the plates.

1893—*A Companion for the Queensland Student of Plant Life.*

1894—*Botany Abridged.*

1895—*A Half-Century of Notes for the Guidance of Amateur Fruit Growers; to which is appended A Comprehensive list of the Fruit-bearing Plants from Time to Time Introduced into Queensland.* Bull. No. 5 (2nd ser.), Department of Agriculture, Brisbane.

1897—*A Companion for the Queensland Student of Plant Life and Botany Abridged.* A second edition of two works issued separately in 1893 and 1894 respectively.

1897-1915—*Contributions to the Flora of Queensland* and *Contributions to the Flora of British New Guinea.* A series of papers (mostly small) issued in the *Queensland Agricultural Journal.* These *Contributions* were commenced in the first issue of the *Queensland Agricultural Journal* in July, 1897, and the last appeared posthumously in July, 1915.

1899-1902—*The Queensland Flora.* This work consists of six volumes, the first published in 1899 and the last in 1902. Bailey had an admiration for George Bentham, the author of the *Flora Australiensis*, that amounted almost to worship. He did not alter Bentham's descriptions except in a very few cases, so the work is largely a compilation from the *Flora Australiensis* plus additions made to the known flora of Queensland by Mueller and Bailey himself. A *General Index* to the work was published as a separate volume three years later (1905) from finance supplied by a visitor to Australia, Mr. F. E. Klotten of Frankfurt-am-Main, Germany.

1907—*The Weeds and Suspected Poisonous Plants of Queensland.* This was a private venture and appeared in 15 monthly parts. In bound volumes the title page is dated 1906, but the last part did not appear until the following year.

1912—*Comprehensive Catalogue of Queensland Plants.* This was to have been simply a list like previous catalogues (see under 1883—*Synopsis of the Queensland Flora*), but the then Governor of Queensland, Sir Wm. MacGregor, recommended to the Government the advisability of illustrating each family by at least one illustration. This was agreed to, so the work is illustrated by 970 line figures mostly by the writer of the present biographical sketch and 16 coloured plates by Mrs. Ellis Rowan. No date appeared on the title page, the "Prefatory and other Notes" are dated 1909, but a special one prefacing Addenda and Corrigenda is dated 19th December, 1912. The first few copies were received from the printer before Christmas of that year, though the general issue was not made until early 1913. The work forms a useful illustrated companion to *The Queensland Flora.* It included the cryptogams.

Association with Scientific Societies.

F. M. Bailey took a great interest in the scientific life of Australia and was elected an Honorary Member of the Philosophical Society of Queensland in January, 1884. He was a member of the first council of this Society and later (1890-91) President. He was an Honorary Corresponding Member of the Royal Societies of Victoria, Tasmania and South Australia. In 1902 the Royal Society of New South Wales awarded him the Clarke Memorial Medal for outstanding researches in Natural Science. He was elected a corresponding member of the Linnean Society of New South Wales in 1879 and contributed several papers to the earlier volumes of the Proceedings of that Society. He was a fairly regular attendant at meetings of the Australasian (now Australian and New Zealand) Association for the Advancement of Science, and was president of Section D (Biology) at the thirteenth meeting held at Sydney in January, 1911. He was elected a corresponding member of the Pharmaceutical Society of Great Britain in 1892, of the Société Royal Botanique de Belgique in 1897, and of the Royal Botanical Society of Edinburgh in 1905. He joined the Linnean Society of London in 1878 and retained his Fellowship till the day of his death.

PERSONALIA.

In appearance F. M. Bailey was a distinguished looking man, and for at least the last forty years of his life wore a long beard but no moustache. He was of rather sparse build and had drooping eyelids which towards the end he had constantly to prop up. He always wore soft shirts and a narrow black bow-tie. It is doubtful if he ever possessed a dinner or evening suit in his life. I remember on one occasion an invitation from a scientific society for a conversazione being received with "Evening Dress" in small type at the bottom. He tore the invitation into fragments in a rage and threw it into the waste-paper basket. He was exceedingly frugal in habits and had a positive horror of drunkenness, gluttony and bawdy conversation. I remember him going to Government House when (I think) Lady MacGregor said: "Well, Mr. Bailey, I have got your favourite lunch—a stale bun"! He never took a drink of cold water so long as I knew him, as he said it gave him a headache. This must have been a life-time habit, for when collecting in the bush, if facilities for boiling the billy and making tea were not available, he dipped his lunch—probably a stale bun—in a nearby creek. Every night for many years he treated himself to three teaspoonsful of rum—no more or less—in a glass of water. He rarely—at least in later life—took other forms of alcohol. He never lost interest in the practical side of horticulture, and one of his earliest publications issued by the Department of Agriculture was *A Half Century of Notes for the Guidance of the Amateur Fruit Grower.* Like many of his contemporaries in Australian science, he took little interest in the philosophical side of his subject, and Darwinism and all that followed it passed him by, making little or no impression. I suppose there was so much at hand of direct interest, and Europe in those days must have seemed a long way away, that this attitude in Bailey and others is not to be wondered at. He never spread himself to sciences other than botany—at least to any extent—though when Acting Curator of the Queensland Museum he identified birds and mammals for the public as far as the library and collections allowed. He also collected beetles for his friend and distant relative, the celebrated coleopterist, Rev. Thos. Blackburn. He acted on the principle of his favourite poet, Alexander Pope, who wrote: "One science only will one genius fit, so vast is art, so narrow human wit." He was a great reader of poetry, and for years never went to bed without a book of poems under his pillow, though it was the biting wit of Pope or the more subtle one of Goldsmith that appealed most to him. He could quote both authors at length. Pope's contemporary and friend, John Gay, was also quoted in the same way. Although he read them fairly assiduously, poets such as Wordsworth and Tennyson made little real appeal to him. He was, however, a great reader and admirer of Keats and Byron, but he did not quote them extensively. He was a man of extraordinary strong personality with a most lovable and kindly character which was sometimes imposed upon. Indicating his character, it may be mentioned he was a great friend of a German medical man and scientist here, and one time a prominent member of this Society—Dr. Jos. Lauterer. The latter was a great character in his day, and once took a trip round the world. He carried a photograph of F. M. Bailey with him, hung it up in his cabin or room, bowed to it every day, and said "Good morning, Mr. Bailey." Another great friend was Mr. J. H. Simmonds, one time Hon. Secretary of the Field Naturalists Section of the Royal Society and a keen local botanist and conchologist. For many years Mr. Simmonds visited the Bailey grave on the anniversary of F. M. Bailey's death and laid a wreath upon it. These instances indicate the likeableness of a great man.

In religious matters, he was brought up an Independent, but after his marriage in September, 1856, to Anna Maria, the daughter of the Rev. Thos. Waite, an Anglican Clergyman, he attended the Church of England for many years. With age, he became rather unorthodox, rarely attended religious services, and did not claim allegiance to any particular Christian sect. He always dubbed himself a "Deist" and in his own words, "Saw in all nature the work of an Almighty hand." He was created a C.M.G. in 1911. He was buried in the South Brisbane Cemetery. A single daughter, Julia, who kept house for him for many years, was later buried in the same grave. Four of his children survived him, three daughters and a son. The latter was Director of the Botanic Gardens, Brisbane, for some years and for a short time held the dual position of Director of the Botanic Gardens and Government Botanist. Later he was Director of the Botanic Gardens, Adelaide, from which position he retired in 1932. One of his sons, Frederick Manson, is Chief Sylviculturist of the New South Wales Forestry Commission, and another, John Rayer, Curator of the Botanic Gardens, Brisbane. The present writer, who holds the position of Government Botanist of Queensland, is a grandson on the maternal side.

The Royal Society of Queensland

REPORT OF THE COUNCIL FOR 1948

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting the Annual Report of the Society for the year 1948.

At Ordinary Meetings throughout the year four addresses were given and one symposium held ; one meeting was devoted to exhibits, and one to the presentation of papers. The Annual Memorial Lecture, held this year in honour of Dr. Alfred Jefferis Turner, was delivered by Dr. I. M. Mackerras.

Ten original papers were accepted for publication in the Proceedings.

As Members are aware, the Annual Subscription has been raised to twenty-five shillings for Ordinary Members and twelve and sixpence for Associate Members. It is uncertain whether this will cover the increased printing costs, and the Council is considering other possible means of increasing income.

The Council has devoted considerable time to arranging the Library. This work is almost complete, but revision of the catalogue is still necessary.

There are 5 honorary life members, 9 life members, 3 corresponding members, 220 ordinary members, and 1 associate member in the Society. This year the Society has lost 2 members by death and 4 by resignation ; 22 ordinary members and 1 associate member have been elected. The Council decided to remove from the list of members 38 who were several years in arrears with subscriptions (*vide* Rule 15).

Attendance at Council Meetings was as follows :—H. C. Webster, 9 ; E. M. Shepherd, 7 ; D. Hill, 5 ; M. I. R. Scott, 10 ; E. N. Marks, 9 ; B. Baird, 6 ; S. T. Blake, 9 ; M. F. Hickey, 6 ; O. A. Jones, 9 ; A. L. Reimann, 9 ; G. Mack, 9 ; J. H. Simmonds, 8 ; R. F. Langdon, 10.

HUGH C. WEBSTER, President.

Margaret I. R. Scott, Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1948.

RECEIPTS

	£ s. d.	£ s. d.
Balance in Commonwealth Bank, 31/12/47	277 14 9	
Cash in Hand, 31/12/47	2 6 5½	
	280 1 2½	
Less amount owing to Hon. Secretary	0 2 0½	
		279 19 2
Subscriptions—1948	176 8 0	
Life Membership	10 10 0	
Arrears	91 17 6	
Paid in Advance	3 3 0	
		281 18 6
Commonwealth Loan Interest	4 11 3	
Savings Bank Interest	5 16 6	
		10 7 9
Donations		2 2 0
Grant on O. A. Jones Presidential Address		24 19 10
Sale of Reprints		45 6 6
Exchange		0 12 8
		£645 6 5

EXPENDITURE

		£ s. d.	£ s. d.
Government Printer—			
1946 Volume : Cost		291 16 8	
Less Government Subsidy	£123 12 4		
Amount paid in 1947	60 0 0		
		183 12 4	
		108 4 4	
1947 Volume (Parts I & II) on A/c.		191 16 7	
Receipt Books and Subscription Notices		3 10 0	
			303 10 11
Library Insurance			0 19 3
Roneoing			6 15 0
Lanternist			1 0 0
Stationery, Stamps, etc.—			
Hon. Secretary		22 4 2½	
Hon. Librarian		1 18 2½	
Hon. Treasurer		1 10 0	
			25 12 5
Refreshments		7 16 10	
less Collections		6 3 9	
			1 13 1
Donation to Cultural Centre Committee			1 1 0
Subscription to Commonwealth Loan			80 0 0
Savings Certificates			2 0 0
Balance in Commonwealth Bank		216 4 7	
Cash in hand, 31/12/48		6 10 2	
			222 14 9
			£645 6 5

In addition to the Credit Balance shown in the above Statement, the Society holds the following Capital Funds:—

Commonwealth Loan	£200
Savings Certificates	2
	£202

held in safe custody by the Commonwealth Bank of Australia, Queen Street, Brisbane.

Examined and found correct.

L. P. HERDSMAN, Hon. Auditor.

E. N. MARKS, Hon. Treasurer.

25th January, 1949.

Abstract of Proceedings, 28th March, 1949.

The Annual General Meeting of the Society was held in the Geology Department of the University on Monday, 28th March, 1949, with the President (Professor H. C. Webster) in the chair. His Excellency the Governor and about sixty members and friends were present. The minutes of the previous Annual General Meeting were read and confirmed. The Annual Report was adopted and the Balance Sheet received. Mr. D. H. Kemp and Professor W. V. Macfarlane were nominated for Ordinary Membership and Mr. J. Green for Associate Membership.

The following officers were elected for 1949 :—

President : Dr. D. Hill.

Vice-President : Professor M. F. Hickey.

Hon. Secretary : Miss M. I. R. Scott.

Hon. Treasurer : Miss D. F. Sandars.

Librarian : Miss B. Baird.

Editors : Mr. S. T. Blake, Mr. G. Mack.

Members of Council : Dr. O. A. Jones, Mr. E. M. Shepherd, Dr. A. L. Reimann, Mr. J. H. Simmonds, Professor L. J. H. Teakle.

Hon. Auditor : Mr. L. P. Herdsman.

The Presidential Address, entitled " Energy and the Future of Mankind," was delivered by Professor H. C. Webster. A vote of thanks was moved by Professor W. H. Bryan, seconded by Mr. R. F. Langdon, and carried by acclamation.

Abstract of Proceedings, 3rd May, 1949.

The Ordinary Monthly Meeting of the Society was held on Tuesday, 3rd May, with the President (Dr. D. Hill) in the chair. The minutes of the previous meeting were read and confirmed. Professor W. V. Macfarlane and Mr. D. H. Kemp were elected to Ordinary Membership ; and Mr. J. Green to Associate Membership. Mr. T. J. Brockington, Mr. W. G. Maxwell, Mr. P. J. O'Sullivan, Mr. A. K. Sutherland, Mr. G. C. Simmons, and Mr. P. H. Durie were proposed for Ordinary Membership.

Mr. V. Grenning gave an address entitled " Forestry in Queensland," of which the following is an abstract :—" The timber supply position in each State in Australia was briefly dealt with, the situation in Queensland being treated in some detail. The main types of timber being milled in Queensland are hardwoods and hoop and bunya pine representing about three-quarters of the total quantity of timber milled. The other classes are cypress pine, cabinetwoods and miscellaneous species which are of importance but relatively small compared to the two main classes. Approximately two-thirds of the timber cut comes from Crown lands. The virgin hoop pine stands are rapidly disappearing and at the present rate of cut will only last for a few years. In order to make provision for future supplies, the Department has of recent years embarked on a vigorous programme of softwood planting with the object of establishing 200,000 acres as soon as possible. To date 40,000 acres have been established and planting is proceeding at the rate of about 4,000 acres per annum, but it is hoped to increase this. About two-thirds of the hardwood now being milled in Queensland comes from private lands, which are not being protected and managed for the permanent production of this timber. The Department is taking action to provide supplies for the future by re-establishing young forests on cut-over country by natural regeneration, i.e., from the regeneration by natural seed fall from seed trees. The cypress pine forests are re-established by similar methods and to date approximately 500,000 acres of hardwood and cypress pine forests have been given improvement and regeneration treatment. Considerable extension of this work is projected. Reference was also made to the methods adopted for protecting forests from fire and the investigation and research work into the problems of reforestation and utilisation was briefly mentioned."

ABSTRACT OF PROCEEDINGS, 23RD MAY, 1949.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 23rd May, with the President (Dr. Dorothy Hill) in the chair. The meeting was held in conjunction with the Queensland Naturalists' Club. About fifty members of these Societies and friends were present. The minutes of the previous meeting were read and confirmed. The following were elected to Ordinary Membership :—Mr. T. C. Brockington, Mr. W. G. Maxwell, Mr. P. J. O'Sullivan, Mr. A. K. Sutherland, Mr. G. C. Simmons, and Mr. P. H. Durie. The following were nominated for Ordinary Membership :—Mr. D. J. Belford, Mr. J. N. Casey, Mr. W. L. Hawthorne, Mr. Grahame Tweedale, and Mr. John F. G. Wilkinson.

Dr. O. H. Selling gave an address entitled " Upper Cretaceous and Tertiary Plant Remains in Antarctica."

ABSTRACT OF PROCEEDINGS, 27TH JUNE, 1949.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 27th June, with the President (Dr. Dorothy Hill) in the chair. About eighty members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Ordinary Membership :—Mr. D. J. Belford, Mr. J. N. Casey, Mr. W. L. Hawthorne, Mr. Grahame Tweedale, and Mr. John F. G. Wilkinson. Mr. K. S. W. Campbell was nominated for Ordinary Membership.

A film on atomic physics was shown.

ABSTRACT OF PROCEEDINGS, 25TH JULY, 1949.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 25th July, with the President (Dr. Dorothy Hill) in the chair. About twenty-five members and friends were present. The minutes of the previous meeting were confirmed. Mr. K. S. W. Campbell was elected to Ordinary Membership. Mr. B. E. Anderson was nominated for Ordinary Membership.

The following were exhibited :—

" Quartz crystals," by Professor W. H. Bryan.

"Some local commensal animals," by Miss D. Sandars.

"Some eucalypts from the Northern Territory," by Mr. S. T. Blake.

"Photographs from the Atomic Energy Commission," by Professor H. C. Webster.

"Rocks from islands of Torres Strait," by Mr. C. Ogilvie.

"Rocks from the Logan district," by Professor F. W. Whitehouse.

"Carbonized fruits from the Victorian deep leads," by Mr. F. S. Colliver.

"Photographs of a trypanosome from a Platypus," by Dr. I. M. Mackerras. These photographs were sent from Hobart by Dr. C. A. Duncan.

Abstract of Proceedings, 29th August, 1949.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 29th August, with the President (Dr. D. Hill) in the chair. About fifty-five members and friends were present. The minutes of the previous meeting were read and confirmed. Mr. B. E. Anderson was elected to Ordinary Membership. Mr. R. D. Malcolmson, Mr. W. B. Mather, Mr. J. M. Thomson, Professor M. Shaw, and Professor J. H. Lavery were nominated for Ordinary Membership.

Professor W. V. Macfarlane gave an address entitled "Human Reactions to Atomic Radiations : A Survey of 500 Years." The histories of the major natural exposures of man to radiations were related. First the bergsucht of Schneeberg (Saxony) miners from 1410 to the present day was related to uranium products which produced carcinoma of the lung. At Joachimsthal in Czechoslovakia a similar high death rate from cancer of the lung was identified in 1926. Probably 3,000 miners had died from this radium-induced disease in five centuries. At least 200 doctors, technicians, patients and nurses had died from skin-cancer engendered by X-rays since 1895. At Orange in New Jersey from 1917-24, 19 cases of radium poisoning causing sarcoma of bone, or aplastic anaemia were recorded. Finally, in 1945, the atom bombs on Japan exposed thousands to acute radiation-injury—depilation, vascular damage, and aplastic anaemia, with death from intercurrent infection.

The mechanism of these processes was considered. Essentially all damage was due to ionisation which, if intense enough, destroyed living protoplasm. In smaller doses the alpha, beta, gamma rays, neutrons or protons ionised water or solutes to produce reducing or oxidising substances which destroyed enzymes and proteins. Other ions forming in the nucleo-protein of chromosomes caused gene-mutations which were lethal at the subsequent division. Chromosomes also broke or divided irregularly or became adherent to each other and prevented normal development. All these mechanisms help to account for the damaging or therapeutic effects of radiations.

The carcinogenetic effects from e.g., short-range alpha-particles or neutrons are more difficult to account for. It seemed likely that slow changes were set up in cells by ions, which might act like other carcinogens (amidofluorene) which sensitised the cells. The cells then might divide erratically as the result of any mild irritant such as bronchitis or dust.

Abstract of Proceedings, 26th September, 1949.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 26th September, with the President (Dr. Dorothy Hill) in the chair. About seventy-five members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Ordinary Membership :—Mr. W. B. Mather, Mr. R. D. Malcolmson, Professor M. Shaw, Professor J. H. Lavery, and Mr. J. M. Thomson.

Mr. R. F. Langdon presented a paper entitled "A New Ergot from Queensland."

Two addresses were given. Professor J. F. Bonner spoke on " Recent Adventures in Plant Physiology," and Professor K. C. Hammer spoke on " Photoperiodism."

Abstract of Proceedings, 31st October, 1949.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 31st October, with the President (Dr. D. Hill) in the chair. About thirty-five members and friends were present. The minutes of the previous meeting were confirmed. Professor W. Stephenson and Dr. W. A. McDougall were nominated for Ordinary Membership.

Mr. J. S. Just gave the meeting details of the Science House project as far as it has gone, and after stating the names of the various interested bodies advised that a " Ways and Means " Committee had been formed on which were himself as Chairman, Professor Wilkinson, Mr. G. F. Cuppaidge, Professor Cummings, and Mr. R. F. G. Wilson. The Committee had set out as an objective a building of approximately 9,000 square feet in area and containing a library with store room in the basement, a large and a small lecture room, committee rooms, offices and amenities block at a then estimated cost of £35,000. After dealing with interviews and deputations which had taken place between members of the Government and the Committee, Mr. Just went on to state that it was anticipated that bodies such as ourselves and others should make a levy on members amounting to, say, 25/- per member over five years as a contribution towards the capital cost of the building. As over 7,000 members were involved a substantial basic sum would be assured. Other bodies may care to put in investment over and above that levied sum. The levied sum would be treated as normal capital, whilst other investments may or may not be treated as debentures at the wish of the interested bodies. It was also expected that donations from interested persons and bodies would make a substantial sum. He pointed out that tentatively the " Ways and Means " Committee had suggested that the management should be in the hands of a Board of Directors nominated by those who contributed towards the cost of the building on the basis of one nominee for each £1,000 contributed. Bodies contributing less than £1,000 could join together to elect their own representative, but that was a matter for final discussion. Mr. Just also drew attention to the Lord Mayor's suggestion that a cultural centre should be created at the foot of Albert Street, and added that no more worthy object than Science House could be put forward as forming the first building to form part of a cultural block in that centre. In connection with the use of the building, it was pointed out that as well as rentals from lecture rooms it was suggested that the combined libraries of the constituent bodies should be housed on the one floor under a competent librarian and that, whilst retaining their entirety, would be available to all constituent body members. This library would form the nucleus of the most important scientific and technical library within the Commonwealth. This library, in itself, makes the effort well worthy of Government support and it was hoped that help would soon be forthcoming. Mr. Just answered several questions.

The following papers were presented :—

" Contributions to the Geology of Brisbane. No. 1. Local Applications of the Standard Stratigraphical Nomenclature," by W. H. Bryan and O. A. Jones.

" Marine Insects," by I. M. Mackerras.

Abstract of Proceedings, 28th November, 1949.

A Special Meeting of the Society was held in the Geology Department of the University on Monday, 28th November, with the President (Dr. Dorothy Hill) in the chair. The business of the meeting was the appointment of a Trustee to fill the vacancy caused by the resignation of Mr. J. B. Henderson. On the motion of Mr. S. T. Blake, seconded by Mr. J. H. Simmonds, Dr. E. O. Marks was appointed.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 28th November, with the President (Dr. Dorothy Hill) in the chair. About forty members and friends were present. The minutes of the previous meeting were confirmed. Professor W. Stephenson and Dr. W. A. MacDougall were elected to Ordinary Membership.

The following papers were read by title :—

" Additions to the Flora of Arnhem Land," by C. T. White.

" Revision of Bregmaceros with Descriptions of Australian Larval Forms," by I. S. R. Munro.

" Heavy Mineral Beach sands of Southern Queensland, Part II," by A. W. Beasley.

Mr. C. T. White delivered a memorial lecture entitled " F. M. Bailey : His life and work."

Professor F. W. Whitehouse exhibited a series of cephalopod faunas from various horizons in Western Queensland ranging from the bottom to the middle of the Ordovician, having close affinities with the faunas of corresponding ages from the Boreal Province of the Northern Hemisphere.

Mr. W. G. H. Maxwell exhibited brachiopods collected by Mr. J. H. Reid, from beds occurring to the south of Mount Morgan. They belong to the new genus, *Cyrtospirifer reidi*, and indicate the age of these beds to be upper Devonian. These are the most southern Upper Devonian marine beds which have been found in Queensland.

CHANGES IN MEMBERSHIP

New Members.

Anderson, B. E.	c/- Cardno & Davies, New Zealand Chambers, Queen Street, Brisbane.
Belford, D. J., B.Sc.	c/- Australian Petroleum Company, Port Moresby.
Brockington, T. J.	McNaughton Street, Redcliffe.
Campbell, K. S. W., B.Sc.	Geology Department, University.
Casey, J. N., B.Sc.	Bureau of Mineral Resources, Geology and Geophysics, Canberra.
Durie, P. H., B.Sc.	Veterinary Parasitology Lab., C.S.I.R.O., Yeerongpilly.
Hawthorn, W. L., B.Sc.	Geological Survey, Brisbane.
Kemp, D. H.	56 Heath Street, East Brisbane.
Lavery, Prof. J. H., M.E., B.Sc.	Engineering Dept., University, Brisbane.
MacDougall, W. A., D.Sc.	Dept. of Agriculture and Stock, Brisbane.
Macfarlane, Prof. W. V., M.A., M.D.	Physiology Dept., University.
Malcolmson, R. D., B.Sc.	Physics Dept., University.
Mather, W. B.	Zoology Dept., University.
Maxwell, W. G. H.	Geology Dept., University.
O'Sullivan, P. J., B.Agr.Sc.	Animal Health Station, Yeerongpilly.
Shaw, Prof. M., M.Eng., M.Mech.E., M.I.Mech.E., A.M.I.E. (Aust.)	Engineering Dept., University.
Simmons, G. C., B.Sc.	Animal Health Station, Yeerongpilly.
Stephenson, Prof. W., Ph.D.	Zoology Dept., University, Brisbane.
Sutherland, A. K., B.V.Sc., M.S.	Animal Health Station, Yeerongpilly.
Thomson, J. M.	Fisheries Research Station, Dunwich.
Tweedale, G., B.Sc.,	Geology Dept., University.
Wilkinson, J. F. G., B.Sc.	Geology Dept., University.

Associate Member.

Green, J.	Botany Dept., University.

Resignations.

Earnshaw, Dr. P. A.
Ellis, C.
Fisher, Dr. E.
Fraser, C. S.
Hamlyn-Harris, R.
Lamberton, J. A.
McConnell, Miss U.
Mackenzie, A. D.
Macpherson, Dr. R. K.
Marks, Dr. A.
Phillips, Dr. B. J.
Price, Dr. T. A.
Webb. L. J.

Death.

Bick, E.

GUIDE FOR THE PREPARATION OF SYNOPSES

1. PURPOSE.

It is desirable that each paper be accompanied by a synopsis preferably appearing at the beginning. This synopsis is not part of the paper; it is intended to convey briefly the content of the paper, to draw attention to all new information and to the main conclusions. It should be factual.

2. STYLE OF WRITING.

The synopsis should be written concisely and in normal rather than abbreviated English. It is preferable to use the third person. Where possible use standard rather than proprietary terms, and avoid unnecessary contracting.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The synopsis should therefore be intelligible in itself without reference to the paper, for example it should not cite sections or illustrations by their numerical references in the text.

3. CONTENT.

The title of the paper is usually read as part of the synopsis. The opening sentence should be framed accordingly and repetition of the title avoided. If the title is insufficiently comprehensive the opening should indicate the subjects covered. Usually the beginning of a synopsis should state the objective of the investigation.

It is sometimes valuable to indicate the treatment of the subject by such words as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

It should contain the names of any new compound, mineral, species, etc., and any new numerical data, such as physical constants; if this is not possible it should draw attention to them. It is important to refer to new items and observations, even though some are incidental to the main purpose of the paper; such information may otherwise be hidden though it is often very useful.

When giving experimental results the synopsis should indicate the methods used; for new methods the basic principle, range of operation and degree of accuracy should be given.

4. DETAIL OF LAYOUT.

It is impossible to recommend a standard length for a synopsis. It should, however, be concise and should not normally exceed 100 words.

If it is necessary to refer to earlier work in the summary, the reference should always be given in the same manner as in the text. Otherwise references should be left out.

When a synopsis is completed, the author is urged to revise it carefully, removing redundant words, clarifying obscurities and rectifying errors in copying from the paper. Particular attention should be paid by him to scientific and proper names, numerical data and chemical and mathematical formulae.

CONTENTS

Vol. LXI.

PROCEEDINGS
OF THE
ROYAL SOCIETY
OF
QUEENSLAND
FOR 1950

VOL. LXII.

This volume includes the
C. T. WHITE MEMORIAL SUPPLEMENT

ISSUED 15th SEPTEMBER, 1952.

PRICE: TWENTY-FIVE SHILLINGS.

Printed for the Society
by
A. H. TUCKER, Government Printer, Brisbane.

The Royal Society of Queensland.

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HIS EXCELLENCY LIEUT.-GENERAL SIR JOHN D. LAVARACK, C.B., C.M.G., D.S.O., C. de G., K.B.E.

OFFICERS, 1950

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CONTENTS

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NOTICE TO AUTHORS

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1. Each paper should be accompanied by the author's name, degrees and official address.

2. Papers must be complete and in a form suitable for publication when communicated to the Society and should be as concise as possible.

3. Papers must be accompanied by a synopsis prepared according to the direction given on the inside of the back cover.

4. Papers should be in double-spaced typescript on one side of the paper with ample margins.

5. The use of italics in the text should be restricted to generic and specific names, foreign words, and titles of periodicals.

6. The cost of author's corrections to proof above what the Council considers a reasonable amount, must be borne by the author.

7. Unless otherwise specified each author will be supplied with fifty separate copies of his paper. Any number exceeding this may be obtained at approximately cost price.

8. All references should be listed at the end of each paper and arranged alphabetically under authors' names, *e.g.*,

   Keilin, D. (1929) Proc. Roy. Soc. B., vol. 104, p. 207.

   Lesage, P. (1895) Ann.Sci. Nat. Bot., vol. 1, p. 309.

   The corresponding references in the text should be:

   "Keilin (1929)", "Lesage (1895)".

9. The size of the printed plate will not exceed 8 in. x 4½ in., and drawings may be to this size, or preferably to a convenient small multiple thereof. The effect of the necessary reduction on lettering and fine detail should be borne in mind. Text figures should be drawn for reduction to a width not exceeding 4 in.

10. Drawing in line should be executed in intensely black ink such as good India ink, on a smooth surface, preferably Bristol board. Excessively fine, scratchy, or faint lines are to be avoided. Tints or washes cannot be reproduced in line drawings, in which the maximum degree of contrast is necessary.

11. Drawings or photographs for reproduction in half-tone should, where possible, be grouped for reproduction on one plate. They should be done or mounted on a smooth surface, such as Bristol board, as the grain of most drawing papers becomes visible on reproduction. Single photographs should be sent flat and unmounted. All prints should be on glossy bromide or gas-light paper.

Vol. LXII., No. 1.

Proceedings of the Royal Society of Queensland.

PRESIDENTIAL ADDRESS.

By Dorothy Hill, D.Sc., Ph.D., Geology Department, University of Queensland.

(*Delivered before the Royal Society of Queensland, 27th March,* 1950; *issued separately* 15*th October,* 1951.)

During the year, the Society lost a valued member by the death of Mr. E. W. Bick.

Ernest William Bick was born in England, and came to Queensland with his parents as a child in 1884. He was employed by the Queensland Acclimatization Society at its gardens at Bowen Park, where he became propagator. He became horticulturist at Government House in 1907, and later transferred to the Botanic Gardens as collector. He went on his first collecting trip in 1910 to Torres Strait and the Gulf of Carpentaria with Sir William MacGregor, and later he collected in many parts of Queensland. On the retirement of J. F. Bailey in 1915, he became Curator of the Brisbane Botanic Gardens, a position which he retained until his retirement in 1940.

His membership of the Royal Society of Queensland began in 1918; he became Hon. Treasurer in 1922, and continued in that office until 1947, when he was elected an Honorary Life Member in recognition of his outstanding service to the Society. He was for many years President of the Horticultural Society of Queensland; he was a Past President of the Queensland Orchid Society and the Queensland Naturalists' Club, and a Vice-President of the Queensland Acclimatization Society at the time of his death. He also served as Hon. Auditor of the Naturalists' Club, and of the Entomological Society of Queensland. He represented Queensland as a nominee of the Department of Agriculture and Stock at several meetings of the Australian and New Zealand Association for the Advancement of Science. He died in 1949, and is survived by his wife, son, and daughter.

THE ORDOVICIAN CORALS.

(With Text Figs. 1-4.)

I. INTRODUCTION.

The Ordovician corals may all be placed in two orders, the Tabulata and the Rugosa. The Tabulata appeared first in Chazy times in the early Middle Ordovician in the shallow seas associated with the Appalachian geosyncline of eastern North America, and they remained predominant throughout the period. The Tabulata may be considered under six families, Chaetetidae, Calapoeciidae, Syringoporidae, Heliolitidae, Halysitidae and Favositidae, the first three appearing before the zone of *Nemagraptus gracilis* in Chazy times, and the last three in Trenton times, between the zones of *Climacograptus peltifer* and *Climacograptus* *linearis* inclusive. The Rugosa first appeared in two families, Streptelasmidae and Stauriidae, in Black River strata (Zone of *Nemagraptus gracilis*), and these two families alone characterise the remainder of the Ordovician. The number of sub-families under each of these families is small, at the most three, and the number of genera also is small.

The Tabulata are always colonial, as are the Stauriidae, but the Streptelasmidae are predominantly solitary. The Ordovician Rugosa show no dissepiments and in this respect are more primitive than the dominantly dissepimented Rugosa of later periods.

The geographical distribution of these Ordovician corals (see text figs.) is, especially at first, more restricted than in later periods. The subarctic regions seem specially favoured. The Chazy fauna, which might perhaps be called the *Lichenaria* fauna after its dominant genus, and the Black River fauna, which might similarly be called the *Lambeophyllum-Tetradium* fauna, seem to be confined to the Appalachian seas, with the exception of a possible Black River *Tetradium* occurring on Bear Island, south of Spitzbergen. In the Trenton of N. America and the Upper Caradocian of Britain (*i.e.*, zones of *Climacograptus peltifer* to *Pleurograptus linearis* inclusive) corals are found not only in Appalachian seas but also in the Caledonian seas of northern Europe and the Himalayan seas of central Asia. The faunas of all three regions are essentially similar, and we must suppose relatively free migration from N. America, though it is possible that the Heliolitidae, Halysitidae and perhaps the Favositidae, which first appeared during this time, may have originated in Caledonian seas and spread to N. America. The fauna of all three regions may be called the *Streptelasma* fauna from the importance of this genus.

By Cincinnatian times (representing the graptolite zone of *Dicellograptus anceps*) a coral fauna had appeared in Tasmania, and this again is of genera characteristic of Europe and N. America at that time, indicating free migration. Corals continued richly developed in N. America and Europe, and the Upper Ordovician or Heliolitid fauna is a not greatly modified *Streptelasma* fauna, its most striking development perhaps being the wealth of Heliolitidae in the Scandinavian region.

It is to be noted that the present geographical distribution of Ordovician corals is in the temperate or subarctic regions of to-day and not at all in the equatorial regions; and this is in marked contrast to the maximum development in equatorial regions of the reef corals of to-day.

Facies faunas in Ordovician corals seem to be two (Foerste, 1924, p. 32). One consists of small solitary non-dissepimented *Streptelasma* and perforate stratiform Tabulata like *Protaraea*; and this is an obvious analogue to the *Cyathaxonia* fauna of the Lower Carboniferous which in turn is an analogue of the present day coral fauna of cold, deep or cloudy waters. In Ohio, Indiana and Kentucky, it characterises richly fossiliferous limestones and clays. The other consists of the compound Rugosa *Favistella*, the coenenchymate Tabulata *Calapoecia*, and the chaetetid *Tetradium*. Possibly this is an analogue of the compound or "reef" coral fauna of the Carboniferous. It characterises the more arenaceous (? clearer water) phases of the Richmond, especially on the west side of the Cincinnati geanticline, and forms "coral reefs" with wide lateral but little (a few inches) vertical extent in which the coralla were not very closely spaced.

Morphological Changes.—All Ordovician Rugosa and Tabulata, except the later Heliolitidae and Calapoeciinae, are relatively simple morphologically. The absence of septa in the narrow-celled Lichenariinae, Tetradiinae and Chaetetinae seems a very primitive feature; the only variables in this family in the Ordovician are shape of corallum (in the Tetradiinae, from simple branching to halysitoid, complex halysitoid and massive hemispherical), and nature of increase, peripheral in Lichenariinae, quadripartite in Tetradiinae and bipartite in Chaetetinae. The Favositidae have septa, but they are short and equal and each consists of a vertical series of separate trabeculae (spines); these show no changes during the Ordovician, neither do the tabulae;

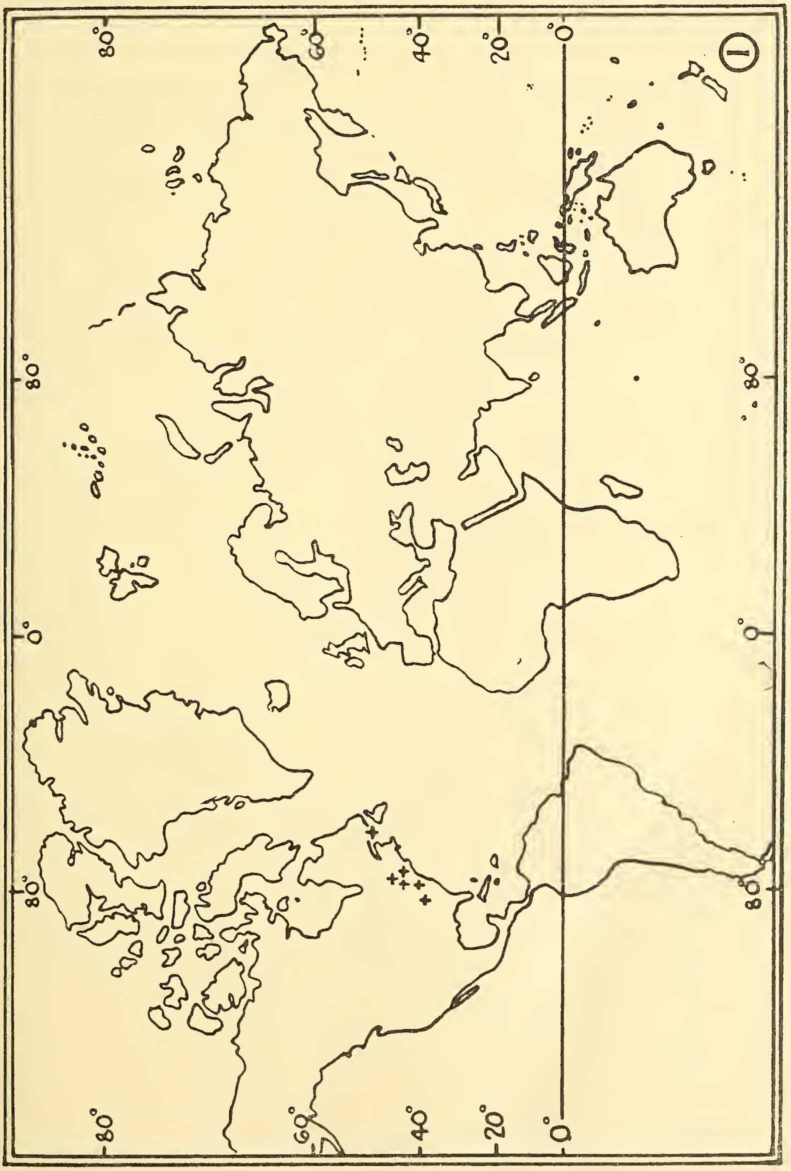

Fig. 1.—Occurrence of Middle Ordovician Chazy *Lichenaria* fauna (pre-*Nemagraptus gracilis* zone).

the walls remain unthickened, and there is no interstitial tissue, but the mural pores are sometimes at the angles and sometimes in the middle of the walls. The Halysitidae show lability in the shape of the corallites, which may depart from the usual oval to a polygonal section, and may form more than one row in the chains; but their tabulae and septa are like those of *Favosites*, though only 12 septa are developed. Post-Ordovician *Halysites* may develop vertical tubuli between corallites. The Ordovician Syringoporidae have primitive, sagging tabulae, not infundibuliform like those of later periods; their septa are like those

Fig. 2.—Occurrence of Middle Ordovician Black R. *Lambeophyllum-Tetradium* fauna (*Nemagraptus gracilis* zone).

of *Halysites*; connecting tubules appear by *D. anceps* time, and variation in shape, to give prismatic corallites, is present but not in later periods.

In two families of Tabulata, Calapoeciidae and Heliolitidae, interstitial tissue develops between tabularia, and greater lability is shown in these families in the Upper Ordovician than in later times. In the Calapoeciidae, horizontal canaliculae connecting neighbouring tabulae develop in horizontal rows between extensions of the septa which may number 16, 20 or 24 in different species. In the Heliolitidae the interstitial tissue may consist of small, horizontally based arched plates; separate trabeculae may develop at right angles to these arched plates; or the trabeculae may be so thick as to fill the interstitial space,

Fig. 3.—Occurrence of Middle Ordovician Trenton *Streptelasma* fauna (Zones of *Climacograptus peltifer* to *Pleurograptus linearis* inclusive).

when they may become arranged in a polygonal spacing. The septa remain twelve in number and equal, and the tabulae may become highly domed. In one genus, septa and walls become cribriform.

The Rugose corals of the Ordovician lack dissepiments, the minor septa remain short, and the tabulae are simple domes. In the Stauriidae the septa are simple vertical plates, but in the Streptelasmidae the axial edge is lobed. The Stauriidae show little or no lability, but in *D. anceps* time some of the solitary Streptelasmids became triangular in section; in others the septa developed a wider margin of lobes axially, and formed an axial structure; in yet others the septa withdrew from the axis and lobing became unimportant.

Fig. 4.—Occurrence of Upper Ordovician Richmond Heliolitid fauna (zone of *Dicellograptus anceps*).

The *phylogeny* of Ordovician corals is a subject of discussion. It is not difficult, within each family, to work out at least temporarily satisfactory lines of descent from the oldest species herein assigned to each family. Thus, in the Chaetetidae, the Tetradiinae and Chaetetinae could be considered derived from Lichenariinae by a change in the method of increase, from dominantly lateral or peripheral in *Lichenaria* to quadripartite in *Tetradium* to incomplete bipartite in *Chaetetes*, the imperforate and aseptate walls characteristic of the sub-order being retained throughout. In the Calapoeciidae, the Nyctoporinae may be presumed with perhaps less certainty to have given rise to the Calapoeciinae by the development of a characteristic common tissue. The Syringoporidae may perhaps be considered descended from *Eofletcheria incerta*; though here further evidence from septal structure is desirable. The Heliolitidae can all be satisfactorily derived from *Protaraea* or *Coccoseris* though Kiaer (1899, 1904) suggests a different phylogeny, and the Halysitidae from the earliest *Halysites* sp. The Favositidae developed naturally from *Palaeofavosites.* In the Rugosa, Streptelasmidae can be considered to have developed from *Lambeophyllum* by the axial denticulation of the septa. The Stauriidae seem clearly derived from the earliest *Favistella.* Weissermel (1897) considers both *Columnaria* and *Streptelasma* to have developed from a *Streptelasma*-like ancestor.

When we consider the relation between the various families our speculations are less satisfactory. Sardeson (1924 fide Okulitch (1935)) considers it possible to derive both Tabulata and Rugosa from *Tetradium;* Bassler (in litteris) suggests that *Lichenaria* is a Rugose coral and that it may have been the ancestor of all Palaeozoic corals. One or more of these earliest corals may have arisen from soft-bodied forms. Possibly the earliest Calapoeciidae, *Billingsaria* and *Nyctopora* arose from *Lichenaria* by the development of septa, but this does not seem very likely. There may be a link between the Syringoporidae and Calapoeciidae; the fasciculate Syringoporid *Reuschia* was indeed placed by Kiaer (1930) with the Calapoeciidae. Also, the Halysitidae may have been derived from *Eofletcheria* by the assumption of its characteristic mode of increase, and the fixing of the septal number at 12; possibly the Heliolitidae, with 12 septa, may be derived from Halysitidae by the development of coenenchyme. But once again these speculations seem idle without detailed studies. Perhaps the Favositidae evolved from the Lichenariinae by the development of septa accompanied by the appearance of mural pores which may have been the result of crenulation forming at the angles of the walls and becoming pierced at the apices of the folds; or they may have derived from the Halysitidae through *Halysites gracilis.*

It is difficult to see how the Rugosa Streptelasmidae with two orders of pinnately inserted septa could have derived from any Tabulata; and it is also difficult to see how this family is related to the Stauriidae, though the common possession of two orders of septa suggests a relationship.

In the investigation of these early and important phylogenies, our North American colleagues have the great advantage of the occurrence within their territories of the earliest Tabulata and Rugosa, and one looks forward with interest to their future work on them.

II. CLASSIFICATION.

Class **Anthozoa** Ehrenberg 1834 (less Hydrozoa).

Subclass **Zoantha** de Blainville 1834 (= Order Zoantharia Edwards 1835).

Order **Tabulata** Edwards and Haime 1850 (as Sub-order).

Family **Chaetetidae.**

Family **Calapoeciidae**

Family **Syringoporidae.**

Family **Halysitidae.**

Family **Favositidae.**

Family **Heliolitidae.**

Order **Rugosa** Edwards and Haime 1850 (as Sub-order).

Family **Streptelasmidae.**

Family **Stauriidae.**

ORDER **TABULATA.**

Corallum compound with very slender corallites; septa short, equal (except in Nyctoporinae, where two orders are present, alternating), frequently twelve in number; each a vertical series of spines; walls often perforate; tabulae complete or sometimes infundibuliform; extratabularial tissue ("coenenchyme") may be developed.

The Order Tabulata has had many changes in its systematics. As proposed by Edwards and Haime (1850) it included several genera which have since proved to belong to other orders, subclasses or even phyla, such as the scleractinians *Pocillopora* and *Seriatopora,* the hydrocoralline *Millepora,* the stromatoporoid *Labechia,* the alcyonarian *Heliopora* and the polyzoans *Fistulipora, Stenopora, Constellaria, Dendropora* and *Monticulipora.* As the true affinities of these misfits were discovered it came to be thought that there was no such biological entity as the Tabulata, and the remaining genera were distributed among the other Anthozoa, chiefly in the Scleractinia and Alcyonaria, but sometimes in specially named orders (Lindström (1876), Zittel (1879), Nicholson (1879), q.v. for references and historical summary, Sardeson (1896), Gerth (1908) and Okulitch (1936b)).

The six families listed, with a few more from the later Palaeozoic rocks, seem to me, however, to form an order clearly distinguishable from the Alcyonaria, the Rugosa and the Scleractinia, and may well retain Edwards and Haime's name Tabulata. They differ from the Alcyonaria (except *Heliopora*) and resemble the Rugosa and Scleractinia in having skeletons of fibrous (not spicular as in Alcyonaria) $CaCO_3$, arranged in trabeculae in the vertical skeletal elements and in sheets in the horizontal plates. They differ from both Rugosa and Scleractinia in having septa of one order only, and very frequently the number of septa they contain is 12. They are invariably compound, the corallites are invariably slender and tend to communicate with one another by mural pores, connecting tubules, or irregularly perforate wall tissue and coenenchyma.

The Chaetetidae differ from all others in lacking true septa, any vertical plates appearing being new walls forming in increase. Also, the walls are imperforate. Earlier (with Jones, 1940) I regarded the

Heliolitidae as a separate order equivalent to the Rugosa; but later and wider experience with the Tabulata causes me to lay greater stress on the similarities of the Heliolitidae to the other Tabulata, rather than on their differences.

Family **Chaetetidae** (Tribe Chaetetinae Edwards and Haime 1850).

Massive coralla with very slender aseptate corallites with imperforate walls and complete tabulae. M. Ord.—Perm., perhaps also Jurassic.

The "septa" of many authors (Okulitch, 1935) are not septa as in the other Zoantharia, but are new dividing walls formed in bipartite, quadripartite or peripheral increase (Reudemann, 1898).

In Chazy times the Lichenariinae (coralla with unequal increase, either peripheral or lateral) are dominant; from Black River to Trenton times the Tetradiinae (with quadripartite increase) gain the ascendency, and in Richmondian times the Chaetetinae (with incomplete bipartite increase) appear, the Tetradiinae wane, and the Lichenariinae have disappeared.

Sub-family LICHENARIINAE Okulitch 1936.

Increase is unequal but complete, off-sets arising near the margins of older corallites. M. Ord., N. Amer., Scot.

Lichenaria† Winchell and Schuchert 1895 (=*Lamottia* Raymond 1924). Corallites polygonal, erect. M. Ord., N. Amer. Figd. Winchell and Schuchert, 1895, pl. G, figs. 10-13.

Palaeoalveolites Okulitch 1935. Corallites inclined, upper walls semicircular. M. Ord., N. Amer. Figd. Bassler, 1932, pl. 7, figs. 2, 3.

Sub-family TETRADIINAE Nicholson 1879.

Increase quadripartite, frequently incomplete. M. and U. Ord.

Tetradium Dana 1848 (=*Prismostylus* Okulitch 1935) as for family. Figd. Bassler, 1932, pl. 21, fig. 19.

Sub-family CHAETETINAE.

Increase bipartite, frequently incomplete so that parts of the corallum are maeandroid. U. Ord.–Perm., perhaps also Jurassic.

Chaetetes Fischer von Waldheim MS. in Eichwald 1829. As for family. Ord. species figd. Oakley, 1936, pl. 12.

Family **Calapoeciidae** nov.

Massive coralla with septa short, thick and spinose, and equal in number in any species; with interseptal mural pores arranged in horizontal rows; coenenchyme may be present, formed by extensions of the tabulae and septa which intersect to enclose tubular spaces between horizontal floors. M. Ord.–L. Sil.

Chazy and Black River forms are without coenenchyme and may have 8 longer septa alternating with 8 shorter (Nyctoporinae). In Trenton times the septa are equal and coenenchyme is developed (Calapoeciinae).

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† For genotypes of, and references to all these genera except *Protrochiscolithus* see Lang, Smith and Thomas, 1940 "Index of Palaeozoic Coral genera." vii + 231 pp., British Museum, London.

Sub-family NYCTOPORINAE nov.

Cerioid coralla with 16 short septa alternating in size. M.–U. Ord.

Nyctopora Nicholson 1879. Corallites with thin walls and septa. M.–U. Ord., N. Amer., Europe; M. Ord., Asia (Spiti). Nicholson, 1879, pl. ix, figs. 3, 3a-c.

Billingsaria Okulitch 1936. Walls thick and septa dilated wedgewise. A columella may occur. M. Ord., N. Amer., Europe. Okulitch, 1936, pl. 1, figs. 3, 4.

Sub-family CALAPOECIINAE.

Cerioid or plocoid coralla; septa equal, 20 or 24. M. Ord.–L. Sil.

Liopora Nicholson and Etheridge 1878. Corallum cerioid. M. Ord., Europe, N. Amer. Cox, 1936, pl. ii, figs. 3a, 3b.

Calapoecia Billings 1865 (=*Columnopora* Nicholson 1874; *Houghtonia* Rominger 1876). Coralla plocoid with coenenchyme more or less well developed; septa 20, equal. M. Ord.–L. Sil., N. Amer., Scandinavia. Cox, 1936, pl. ii, figs. 7-9.

Sarcinula Lamarck 1816 (=*Syringophyllum* Edwards and Haime 1850). Corallum alternatingly plocoid and fasciculate; septa equal, 20 or 24. M. Ord.–L. Sil., N. Europe. Cox, 1936, pl. iv, figs. 4-8.

Family **Syringoporidae** de Fromentel 1861.

Corallum prostrate with corallites conical and anastomosing, or erect and fasciculate with corallites connected by tubules; septa acanthine; wall with fibrous lining; tabulae complete and sagging or infundibuliform. Ord.–Perm.

In Chazy and Trenton times the corallum is fasciculate, without connecting tubules; in the Cincinnatian, connecting tubules appear and in one genus the corallites become polygonal. The tabulae are complete and sagging in all Ordovician forms, not infundibuliform as in Silurian and later forms.

Sub-family SYRINGOPORINAE.

Corallum fasciculate, corallites usually connected by transverse tubules. Ord.–Perm.

Reuschia Kiaer 1930*. Corallites cylindrical, without connecting tubules, but with tabulae absent or complete and sagging. M. Ord., N. Amer.; M.–U. Ord., Scandinavia. Kiaer, 1930, pl. iv, figs. 1-3; Okulitch, 1937, pl. xviii, figs. 1-4.

Arcturia Wilson 1931. Corallites polygonal, not in contact, but with a vertical series of transverse tubuli connecting neighbouring corallites at each wall angle; tabulae complete, sagging, not infundibuliform. U. Ord., Arctic America. Wilson, 1931, pl. iii, figs. 1-3.

Syringopora Goldfuss 1826. Corallites cylindrical, connected by transverse tubules; tabulae complete and sagging (in Ordovician species) or infundibuliform (Sil.–Perm. species). U. Ord., Arctic America and Rocky Mts. See Troedsson, 1928, pl. 43, figs. 2-3 (for Ord. species).

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* Since this paper went to press, Bassler, 1950, *Mem. geol. Soc. Amer.* 44: 266 has founded *Eofletcheria* on *Columnaria incerta* Billings, 1859. To this new genus should be removed those American and Scandinavian Middle Ordovician forms with relatively thin walls and tabulae included in *Reuschia* above; *Reuschia* now includes only thick-walled forms without tabulae, and is known only from the Scandinavian Upper Ordovician.

Family **Halysitidae** (tribe Halysitinae Edwards and Haime 1850).

Compound coralla with slender compressed corallites united in chains, each chain typically of one row of corallites, the ends of the chain being connected to the sides of others; smaller tubules crossed by tabulae may occur between the corallites; walls imperforate, septa acanthine, 12 in number, equal; tabulae complete, sagging. M. Ord.–Gedinnian. Ordovician species show no tubuli between corallites.

Halysites Fischer von Waldheim 1813 (=*Catenipora* Lamarck 1816). Corallites round or oval in transverse section, occasionally with more than one row in a chain when they become polygonal; smaller tubules between corallites rare or absent in Ordovician species. M. Ord.–Sil.; Gedinnian in Asia Minor. Lambe, 1899, pl. iii, figs. 5-7.

Labyrinthites Lambe 1906. Corallites prismatic, thick walled, in extremely short chains, frequently with two rows of corallites in a chain; no interstitial tubules. Ord., Arctic America. Lambe, 1906, p. 328, text fig.

Family **Favositidae** Edwards and Haime 1850.

Massive coralla without coenenchyme; with slender prismatic corallites with mural pores; septa short, equal, spinose; tabulae complete. U. Ord.–Perm.

Early upper Ordovician forms have the mural pores at the angles of the walls (*Palaeofavosites*); towards the top of the Ordovician these are joined by forms with pores in the middles of the walls.

Sub-family FAVOSITINAE.

Corallum with prismatic, thin-walled corallites. U. Ord.–U. Dev.

Palaeofavosites Twenhofel 1914. Mural pores occur predominantly at the angles of the walls. U. Ord.–M. Sil. Lambe, 1899, pl. i, fig. 2.

Favosites Lamarck 1816. Mural pores occur predominantly in the middle of the walls. U. Ord.–M. Dev. Lambe, 1899, pl. i, fig. 1.

Family **Heliolitidae** Lindström 1876.

Massive coralla with slender corallites separated by coenenchyme, each corallite with 12 equal spinose septa and complete tabulae. M. Ord.–U. Dev.

The earliest Heliolitidae (Trenton) have thick trabeculae and little coenenchyme and some may have perforate septa; upper Ordovician forms are very numerous and diverse.

Sub-family COCCOSERINAE Lindström 1899.

Encrusting or discoid coralla with coenenchyme almost absent or tubular, the tubuli being closed or restricted by thickening of the vertical trabeculae forming their walls; each corallite filled or almost filled by thick septal trabeculae which curve upwards and inwards to become vertical at the axis. M. Ord.–L. Sil., Europe, N. Amer., Aust.

Protaraea Edwards and Haime 1851 (=*Stylaraea* Seebach 1866 non Edwards and Haime 1851, *Tumularia* Robinson 1916). Coenenchyme very narrow or absent, trabeculae very stout. M. Ord.–L. Sil., N. Amer., Europe, and Aust. Foerste, 1924.

Coccoseris Eichwald 1855. Coenenchyme wide; trabeculae so stout that all spaces are filled. U. Ord.–L. Sil., Europe. Lindström, 1899, pl. xii, figs. 3, 4, 6, 7.

Acidolites Lang, Smith and Thomas 1940 (=*Acantholithus* Lindström 1899 non Stimpson, 1858). Coenenchyme wide, tubular; trabeculae relatively slender, leaving spaces crossed by tabulae. M. Ord.–L. Sil., Europe, Tasmania. Lindström 1899, pl. xi, figs. 23, 24, 26, 30.

Trochiscolithus Kiaer 1899. Corallum branching; coenenchyme tubular, moderately wide; axis of branch with slender trabeculae forming occasionally perforate septa and walls; outer part of branch with all spaces filled by thickening of the trabeculae. M. and U. Ord., Europe. Kiaer, 1904, fig. 5-6, 3.

Protrochiscolithus Troedsson 1928. Coenenchyme very narrow; trabeculae slender, forming occasionally perforate walls and leaving spaces in the corallum. U. Ord., Arctic N. Amer. Troedsson, 1928, pl. 30.

Urceopora Eichwald 1855 and *Stylidium* Eichwald 1855 from the Baltic are possibly Coccoserids, but thin sections are required.

Sub-family PROPORINAE nov.

Massive coralla with slender tubular corallites separated by a coenenchyme of domed plates and isolated trabeculae; septa 12, spinose, equal. M. Ord.–U. Sil.

Propora Edwards and Haime 1849 (*Lyellia* Edwards and Haime 1851, *Pinacopora* Nicholson and Etheridge 1878, *Nicholsonia* Kiaer 1899 non Schlüter 1885). Thickening of trabeculae not greater in peripheral or surface zones than in axial or lower zones of the corallum; tabulae flat or sagging. M. Ord.–U. Sil. Lindström, 1899, pl. viii, figs. 8-10.

Plasmoporella Kiaer 1899. Trabeculae very slender; tabulae domed and complete or incomplete. U. Ord.–M. Sil., Europe, Tasmania, and N. Amer. Kiaer, 1899, pl. v, figs. 9, 10.

Diploepora Quenstedt 1879. Corallum branching; axial part of branch with slender trabeculae; peripheral part with all spaces filled by thickening of the trabeculae. U. Ord.–Sil., Europe. Kiaer, 1899, pl. v, fig. 7.

Sub-family PROHELIOLITINAE Kiaer 1899.

Massive coralla with slender corallites in contact or polygonal or separated across their angles by one, two or three small coenenchymal tubules, each of which may increase in diameter to form a normal corallite; septa 12, equal, each represented by a single vertical series of very short, downwardly directed, discrete spines. U. Ord.–L. Sil., Europe.

Proheliolites Kiaer 1897 as for sub-family. Kiaer, 1899, pl. iii, figs. 5, 6.

ORDER **RUGOSA.**

Solitary or compound coralla in which, after the insertion of the first six septa, meta-septa are inserted at four points only. Typically there are two series of septa and a varying development of tabulae and dissepiments. The corallum invariably has an epitheca. Compound coralla are formed by axial, peripheral or lateral increase. M. Ord.–U. Perm. Ordovician Rugosa have no dissepiments.

Family **Streptelasmidae** Nicholson 1889.

Solitary conical Rugose corals with short minor septa and without dissepiments; the major septa are denticulate axially; early septal dilatation decreases giving a peripheral stereozone only in adults; tabulae domed, complete or incomplete. M. Ord.–M. Sil.

The width of the axial zone of denticulation of the septa generally increases in Ordovician forms; in the Cincinnatian many species become angulate (especially triangular) in transverse section.

Lambeophyllum Okulitch 1938. Septal denticulations few or absent; no axial structure; in adult stages the axial edges of the major septa of the cardinal quadrant run together to make a wall for each side of the cardinal fossula which contains the long cardinal septum, and the axial edges of the septa in the counter quadrants run together to form a wall along the counter sides of the alar fossulae. M. Ord., N. Amer., Baltic. Okulitch, 1938, p. 99, text fig. B.

Streptelasma Hall 1847. Septa long, axial denticulations few and axial structure narrow. M. Ord.–Sil. Cosmop. Cox, 1937, pl. i, figs. 1, 2.

Grewingkia Dybowski 1873 (=*Kiaerophyllum* Wedekind 1927). Septa short, axial denticulations numerous, axial structure wide and present in young stages. U. Ord., N. Amer., Europe. Wedekind, 1927, pl. i, figs. 8, 9.

Brachyelasma Lang, Smith and Thomas 1940 (=*Dybowskia* Wedekind 1927 non Dall 1876). Axial denticulations few in young stages; in adult stages without axial structure and with septa withdrawn from the axis. U. Ord., Europe. Wedekind 1927, pl. i, figs. 10, 11. Scheffen, 1933, pl. i, figs. 5, 7.

Palaeophyllum Billings, 1858. Phaceloid *Streptelasma*. M.–U. Ord., Canada. Lambe, 1901, pl. vi, fig. 3, 3a, b.

Holophragma Lindström 1896. Calceoloid with cardinal septum on flattened side longer than other septa, but not produced upward into a columella; septa long, so thick as to fill all interseptal loculi and without axial denticulations. ? U. Ord., N. Amer.; Sil., Scandinavia. Lindström 1896, pl. vi, figs. 77, 78, 81. Possibly a halliid.

Coelostylis Lindström 1880. Like *Streptelasma* but with a blade-like columella produced upwards from the axis. M. Ord., Scandinavia. Lindström in Angelin, 1880, pl. i, fig. 11.

Family **Stauriidae** Edwards and Haime 1850.

Compound Rugose corals with small corallites; the minor septa may be short and dissepiments absent, or longer when lonsdaleoid dissepiments may develop. Major septa long, axial edges smooth, no axial structure; tabulae complete, flat or funnel-shaped. M. Ord.–M. Dev. The Ordovician forms are all without dissepiments.

Favistella Dana 1846. Fasciculate or cerioid Rugosa with small corallites with short septa and without dissepiments; tabulae complete and nearly horizontal; walls thin. M. Ord.–L. Sil., cosmop. Lambe, 1901, pl. vi, figs. 1, 1a.

III. SEQUENCE OF FAUNAS.

North America.

Chazy (pre-*Nemagraptus gracilis* zone).

The lower Middle Ordovician Chazy corals may well be the oldest in the world. A record of an earlier occurrence (*Tetradium? simplex* Bassler (1919)) refers to such poorly preserved material that it is doubtful to what phylum it belongs. The Chazy fauna seems to be older than the *Nemagraptus gracilis* zone in the graptolite sequence (though possibly of it) since recent work (Cooper and Cooper, 1946) shows that in Virginia the beds containing it (Newmarket limestone) lie below the Edinburg formation with Normanskill graptolites such as *N. gracilis* and Black River and perhaps early Trenton shelly faunas.

The Chazy corals are all compound and seem all to be Tabulata. Two genera are placed here in the Chaetetidae, one in the Calapoeciidae and the fourth somewhat doubtfully in the Syringoporidae. They are known as follows, from north to south. [In this paragraph, as in all others in this paper citing the occurrence of genera and species in formations, I have relied on figures of thin sections, or on thin sections in the Sedgwick Museum, the British Museum (Natural History) or the University of Queensland; records of Ordovician coral species are in need of precise revision, the names usually being a guide only to the external form or unsectioned appearance of the fossil. Formations are cited so that possible errors in correlation may be rectified.] Mingan formation, Mingan I., *Billingsaria parva* (Bill.) and *Eofletcheria incerta* (Bill. Lambe 1899 and Twenhofel 1938); Aylmer formation, Ottawa valley, the single-tubed *Tetradium cylindricum* Wilson (1921) which according to Okulitch (1935) is conspecific with the Black River *T. syringoporoides* Ulrich; Chazy of L. Champlain region, *B. parva*, Lambe (1899); upper part of lower Chazy (Day Point division) of Vermont, *Lichenaria* (*Lamottia*) *heroensis* Raymond (1925) and at Plattsburg, N.Y.; Newcastle limestone of Virginia, *B. parva,* Cooper and Cooper (1946) (records only); Lenoir of E. Tennessee, Schuchert (1943), *B. parva, Lichenaria prima* Okulitch (1936). The Stones River group of Tennessee and its correlatives in neighbouring states, from which Okulitch (1936) listed Rugose corals, are now regarded as Black River rather than Chazy (Schuchert (1943)).

Lamottia and *Lichenaria* seem to me to be congeneric, though Okulitch (1936) states that perforations occur in the walls of *Lamottia* and not in *Lichenaria;* topotype specimens of *Lamottia* I have examined at the Sedgwick and British Museums do not show perforations. *Lichenaria* forms massive coralla of polygonal tabulate tubules, aseptate and aporose as in the Chaetetidae, in which I place it; increase is apparently peripheral and indicates a sub-family separate from the Chaetetinae and Tetradiinae which I also regard as Chaetetidae. *Tetradium* is aseptate and aporose with tubules 4-sided, but in this early age its species is single-tubed; each tube divides characteristically by quadripartite fission, the new walls growing inwards from the middles of the old walls. This inward growth of the new walls is seen in the bipartite or incomplete fission of typical chaetetids. Okulitch (1939) has suggested how the Black River, Trenton and Richmond tetradiids may have developed from this single-tubed form by an increase in the rate of fission producing at first chain-like or fasciculate coralla, and later cerioid massive coralla.

Billingsaria differs from all other Palaeozoic corals except the later Ordovician *Nyctopora* in possessing the fixed number of 8 long (? lamellar) septa alternating with 8 short septa. It differs from *Nyctopora* by the wedge-like thickening of its septa and by its columella; its corallites communicate by irregular vacuities between the trabeculae. These two genera I regard as forming a distinct Ordovician subfamily, the Nyctoporinae, and there are grounds for believing that it and the Calapoeciinae of the later Ordovician are related. A thin section of *Nyctopora billingsi* Nich. in the British Museum from the Trenton of Nepean Pt., Ottawa, shows a horizontal row of wall pores as in *Calapoecia.*

Fasciculate coralla, whose tubules are slender (about 1 mm.) and aporose, and whose possession of spinose septa is doubtful (compare Lambe (1899) and Okulitch (1937)), but which are crossed by tabulae (occassionally infundibuliform) are assigned to the family Syringoporidae. Bassler (1950) has founded the genus *Eofletcheria* for them.

Nemagraptus gracilis zone.

(Black River.)

As with the Chazy, the relation of the Black River group of the type area to the standard graptolitic succession rests on indirect evidence. The correlation of N. American strata with those of the Black River of the type section in New York State has recently been revised, so that the assessment of Chazy and Black River faunas made by Okulitch (1936, 1938) requires modification. For instance the Stones River formation of Tennessee and its correlatives in neighbouring states are now regarded as Black River, not Chazy (Schuchert (1943)), and the Cloche I. limestone and correlative beds at Pauquette's Rapids in the upper Ottawa Valley are regarded as early Trenton, not Black River (Kay (1937)). The Edinburg formation of Virginia has been found by Cooper and Cooper (1946) to contain shales with graptolites of the *Nemagraptus gracilis* zone intergrading with and laterally equivalent to limestones, etc., with shelly faunas of Black River type, so that it may be deduced that the type Black River is also of the *Nemagraptus gracilis* zone.

In the area of continuous Black River outcrops from New York into S.E. Ontario (Young (1943)) which contains the type area, *Billingsaria* and *E. incerta* seem to have disappeared, though *Lichenaria* is still present. *Tetradium* is now common, being represented by several species in which the rate of fission outsteps the rate of branching, so that thick branched (*T. cellulosum*), halysitoid (*T. halysitoides*) or even hemispherical cerioid coralla (*T. fibratum*) develop alongside *T. syringoporoides* Okulitch (1938, 1939). But the outstanding feature of the Black River fauna is the presence for the first time of Rugosa, the Order in which septa (major and minor) are inserted in only 4 positions in the corallum. The earliest genera seem to be solitary corals—streptelasmids—*Lambeophyllum* Okulitch (1938) and *? Coelostylis* Lindström (1880), (i.e., *"Lindstroemia" whiteavesi* Foerste (1906), description only, no figure available); the latter is columellate, one septum being elongate and swollen axially. In addition, cerioid coralla occur which are usually referred to *"Columnaria"*; but specimens from the type area of Black River strata seem not to have had their internal structure sufficiently figured or described for us to be certain whether they are Rugosa or not. The records usually read *Columnaria halli,* or *Columnaria alveolata,* but the specimens need careful study; many may be *Favistella;* some may be *Lichenaria,* e.g., *Columnaria simplissima* Okulitch. The specimens figured by Lambe (1901) from fault blocks in Renfrew Co., Ontario, seem to be Rugosa, but may well belong to differing genera, and also quite possibly came from early Trenton rather than Black River strata. *Calapoecia* and *Streptelasma* have both been recorded from a fault block at Pauquette's

Rapids, upper Ottawa valley, in strata previously considered Black River but now (Kay (1937)) referred to early Trenton, so that it seems that these two genera may not now be included in the Black River fauna.

In the States south and south-west of New York, e.g., in Tennessee in the Stones River group and its correlatives in neighbouring states, and in the Decorah Formation of Minnesota, there are additional endemic forms. These are the insufficiently described small Rugose cup coral ? *Streptelasma parasiticum* Ulrich (Decorah of Minnesota and Lebanon of Tennessee (Okulitch (1938)), and the compound, cerioid Rugosa *"Columnaria" minor* Bassler from the Kimmswick formation of Tennessee (specimen in B.M.), the colonial Tabulata *Palaeoalveolites carterensis* with reclined corallites and *Lichenaria carterensis* both from the Carters limestone of central Tennessee (Okulitch (1938)), and *L. typa* from the Decorah of Minnesota. Okulitch suggests that *Palaeoalveolites* has mural pores and septal spines and that it is ancestral to the Silurian *Alveolites,* but its structure and affinities require elucidation. It could well be a development from *Lichenaria. Nyctopora* apparently makes its first appearance (specimen in B.M.) in the "Murat" of Virginia; Cooper and Cooper (1946) regard this as post-Chazy, and either pre-Black River or early Black River.

Post-*N. gracilis* to *Pleurograptus linearis* zone.
(Trenton.)

The Trenton group is of considerable extent in N. America, the standard now used (Kay (1937)) extending in Ontario from the base of the Rockland formation to the top of the Gloucester shale; it is roughly equivalent to the three graptolite shales Magog, Canagoharie and Utica, covering the American graptolite zones from *Cyrtograptus tricornis insectiformis* to *Glossograptus quadrimucronatus typus* inclusive which in the British sequence probably represent the zones above *Nemagraptus gracilis* to and including *Pleurograptus linearis* (Thorslund (1940)).

The Trenton coral fauna comes almost entirely from the pre-Utica (i.e., pre-*linearis* zone) section of the Trenton group. At Pauquette's Rapids in a fault block in the upper Ottawa valley a fauna occurs which was previously considered Black River but is now (Kay (1937)), regarded as Rockland. It is distinguished by the first occurrence of *Calapoecia* (as *C. canadensis*) and of *Streptelasma* (as *S. corniculum*) together with the insufficiently known Rugose *"Columnaria" magnifica* Okulitch (1938), a phaceloid species with large corallites, the solitary *Lambeophyllum ? apertum* (Bill.) Okulitch (1938), and the curious *Palaeoalveolites pauquettensis* Okulitch (1938), while Lambe (1901) records also *"Columnaria" halli* Nich., *Lambeophyllum profundum* and *Tetradium fibratum,* and Okulitch (1938) records *Lichenaria typa. Calapoecia* shares with *Liopora* and *Syringophyllum* the possession of a single order of septa, constant in number in the corallites of any one species, and of communicating canals between corallites developed between the septa periodically at the same heights in neighbouring coralla.

From the slightly younger typical development in New York (Trenton) and Ontario (Peterborough), Nicholson (1875) described a small fauna, *"Columnaria alveolata," Streptelasma corniculum* and massive *Tetradium* as in the Rockland formation, with in addition *Nyctopora,* and the earliest Heliotidiae from N. America. These are *Protaraea vetusta* Hall and *Propora goldfussi* (Bill.) with 12 equal septa, though Trenton specimens of the latter typically Richmondian species have not been figured. Foerste (1924) remarks that the Trenton *Protaraea* were unattached except for a small central point, while the later, Richmond forms were encrusting. Both these species are known also from Scandinavia. The Scottish calapoeciid *Liopora* is represented (specimen in B.M.). The Trenton fauna is widespread in N. America. In the Hermitage shale of Tennessee which Schuchert (1943) considers to represent the lower part of the Trenton group, typical species are accompanied by *Lichenaria, Nyctopora crenulata* Bassler (1932) showing lamellar septa, and by *Aulopora,* the latter recorded by Bassler but not figured. If this *Aulopora* is correctly identified it forms the earliest representative of the genus, and the upper Ordovician Syringoporidae may well have developed from it, rather from *Reuschia* as previously suggested.

An interesting first occurrence for America is *Halysites,* from the upper part of the Liskeard formation of L. Timiskaming, Ont., which Kay (1937) correlates with the Coburg limestone and the early part of the Utica shale (*P. linearis* zone). Teichert (1937) has recorded *H. aequabilis* from possibly upper Trenton strata on Iglulik I. in Arctic N. America, together with *Propora lambei* and *Coelostylis ? oppletus,* a solitary Rugose coral with septa highly dilated throughout, their axial parts forming a raised columella in the floor of the calice.

Dicellograptus anceps zone.

Cincinnatian.

The Cincinnatian of N. America (Schuchert (1943)) saw a considerable development of strata; in the typical Ohio-Indiana-Kentucky sequence the Eden and Maysville formations at the base are followed by the Richmond; the two first are usually regarded as equivalent to the Lorraine of New York and the Hudson river group of Vanuscem (1842) and Hall (1847). If the Utica shale is correctly correlated with the British Zone of *P. linearis* (Thorslund (1940)), then the Cincinnatian may be roughly equivalent to the Ashgillian, i.e., to the *Dicellograptus anceps* zone of the British Isles.

Corals do not occur in the Eden or Maysville formations, or in the Lorraine, but are common in the Richmond. In Ohio, Indiana and Kentucky, Foerste (1909) gives a Richmondian assemblage of *Streptelasma,* some solitary and like the *Grewingkia* of Europe, some like *"S. divaricans* Nich.", conical individuals aggregated by their bases, some *"Columnaria"* (various cerioid and phaceloid forms, insufficiently illustrated) with *Calapoecia, Tetradium* of cerioid habit, and encrusting species of *Protaraea.*

In Richmond equivalents in Ontario and Quebec, Foerste (1924) figures a similar fauna with *Propora goldfussi* added. *Palaeophyllum rugosum* Bill., which, according to Lang, Smith and Thomas (1940) is a phaceloid Strepelasmid, is possibly from Richmond strata on L. St. John (Cox (1936)), though Dresser's (1916) map indicates a Trenton age.

It may be that the Red River formation of Manitoba is older than Richmondian; its fauna generally resembles that cited above, but in addition it contains *Halysites gracilis* in which each chain of corallites may consist of more than one row of corallites (Leith (1944)), while in its upper layers *Palaeofavosites* makes its first appearance in America as *P. prolificus* (Foerste (1929) recorded only). In the Stony Mountain formation above the Red River, which seems a Richmond correlative (Okulitch (1943)), the large streptelasmids are angulate (*S. trilobatum*), some of the Streptelasmidae are columellate and calceoloid (*Holophragma anticonvexa* Okulitch), *Halysites* and *Calapoecia* are associated with *Palaeofavosites* and, according to Okulitch, with *Favosites intermedius,* with characters said to be intermediate between those of *Palaeofavosites* and *Favosites.* This would seem to be the first occurrence in America of the Favositidae.

In the N. American Arctic regions (including Alaska) several Richmondian (or possibly Red River) correlatives have been recorded (Cox (1937), Teichert (1937), Roy (1941), Wilson (1931)). *Streptelasma rusticum* occurs with angulate (particularly trilobate) forms and columellate ? *Coelostylis* and *Holophragma.* "*Columnaria*" is recorded (Troedsson (1928)), *Calapoecia* is common, particularly *C. anticostiensis,* with *Halysites, Propora* (often listed as *Plasmopora lambei*), *Syringopora* with tabulae which are not infundibuliform (Miller and Youngquist (1947)), and the curious syringoporid with polygonal corallites, *Arcturia* Wilson (= *Labyrinthites* Troedsson non Lambe). *Labyrinthites* Lambe is a curious form, possibly related to *Halysites,* recorded from C. Chudleigh in Hudson Str. In the probably Richmondian (Red River) C. Calhoun beds of W. Greenland, the heliolitid *Protrochiscolithus* occurs (Troedsson (1928)). *Chaetetes* has been described (Oakley (1936)) and this is possibly the earliest authentic occurrence for a typical member of this long-ranging genus. *Tetradium* seems to be absent.

The Richmond correlative in the Rocky Mountains, the Beaverfoot formation (Wilson (1926)), has large solitary Streptelasmidae resembling *Grewingkia,* some being angulate and trilobate (*S. prolongatum*); others have a columella (? *Coelostylis patellum*). Cerioid and phaceloid "*Columnaria*" (insufficiently figured) occur, and an interesting feature is the phaceloid Rugosa assigned by Wilson to *Diphyphyllum.* These are insufficiently known but appear to represent a new endemic Rugose element in the coral fauna. *Syringopora* has entered here, as in the Arctic regions, with concave, not infundibuliform tabulae, associated with *Calapoecia, Halysites* without interstitial tubules, *Palaeofavosites* and species unfigured but referred to *Favosites. Tetradium* seems to be absent.

On Anticosti Island (Twenhofel (1927)), the English Head and Vaureal formations have a Richmondian fauna, with *Streptelasma rusticum* and large angulate *Streptelasma,* (cf. Cox (1937)), "*Columnaria*" cerioid and fasciculate and insufficiently illustrated, *Calapoecia, Halysites, Propora goldfussi* (Bill.) and *Palaeofavosites.* The Ellis Bay formation is considered by Twenhofel to be post-Richmondian (Gamachian) and indeed its coral fauna contains at least one new element in "*Cyathophyllum*" *ellisense* Twenhofel (1927), in addition to the characteristic Richmond genera. This new form suggests the Silurian *Strombodes* and *Pilophyllum. Aulopora* and *Favosites* also occur in the lists, but no sections are figured. *Tetradium* seems to be absent from Anticosti.

British Isles.

Craighead Limestone (? *Climacograptus peltifer* zone).

The Craighead limestone of Girvan, Scotland, would now seem in all probability to belong to the *Climacograptus peltifer* Zone. Anderson and Pringle (1946) have traced the field relations between fossiliferous olive-green sandy mudstones and limestones as the Craighead Quarry has been extended, and have concluded that the Craighead limestone is a reef phase in these mudstones. As they consider the mudstone fauna to be that of the Balclatchie mudstones, they regard the contemporaneity of the Craighead limestone and Balclatchie mudstones as established, so that the Craighead limestone is younger than the Stinchar limestones. They conclude that the horizon of the Craighead limestone is thus at the top of the Glenkiln shales or the base of the Hartfell, with a slight balance in favour of the former. Bulman (*verb. dict.*), who has recently (1944-47) studied the Balclatchie graptolites of Laggan Burn, considers these to be not younger than the zone of *Climacograptus peltifer,* and not older than the zone of *Nemagraptus gracilis,* and that they are probably of the former zone, i.e., early Caradocian, upper Glenkiln. The Craighead limestone, which contains the oldest coral fauna in the British Isles, is therefore not so old as the Chazy of N. America, but could be coeval with some part of either the Black River or the early Trenton, probably early Trenton; and it is interesting to note therefore that its assemblage of genera is of Trenton rather than Black River or Chazy aspect.

Its Rugosa are probably all Streptelasmidae. *Streptelasma craigense* Nicholson and Etheridge (1878) is the commonest. *S. fossulatum* Wang (1948) could well be *Lambeophyllum,* the typical N. American Black River genus, which seems to persist into early Trenton (Rockland) times. ''*Lindstroemia subduplicata* McCoy'' N. and E. is not columellate like ''*Lindstroemia*'' (? *Coelostylis*) *whiteavesi* Foerste from the Ottawa Black River, but suggests relationship to *Streptelasma aequiseptatum* McCoy of the Robeston Wathen and Coniston limestones. *S. aggregatum* is fasciculate. No ''*Columnaria,*'' so characteristic of the N. American Middle and Upper Ordovician, occurs, and in this particular this Scottish fauna presents a strong contrast to the North American.

The Nyctoporinae are represented by *Billingsaria occidentalis,* though in N. America this genus apparently died out at the end of Chazy times. The Calapoeciinae are represented by *Liopora favosa* which in its structure is quite similar to the Trenton *L. americana* Bassler and to *Calapoecia canadensis.*

As in the Trenton of N. America, the Heliolitidae and Halysitidae are present. The only heliolitid is an irregularly ramose form of very thickened tissue, wrongly referred by Nicholson and Etheridge (1878) to *Heliolites grayi* Edw. and H., but which Kiaer (1932) suggests may be *Trochiscolithus.* This form may however be *Protaraea.* The *Halysites* seems to be the oldest so far recorded; several specimens are in the British Museum.

The Chaetetidae are represented by only one species of *Tetradium,* of a massive type such as characterises the Trenton in N. America; true *Chaetetes* seems absent, for *Chaetetes* sp. Nich. and Eth. (1878) is probably polyzoan.

Whether the Favositidae are already present in the Craighead limestone is very doubtful. Nicholson and Etheridge (1878) described *Favosites girvanensis,* but this is apparently without mural pores or septa, though its walls are crenulate at the angles; it may be referable to the N. American Middle Ordovician *Lichenaria.* The peculiar ''*Thecostegites ?*'' *scoticus* N. and E. is difficult to place. Its corallites are polygonal, with thickened walls, apparently aporose, and open to the surface obliquely suggesting an irregularly dendroid development with thickened walls from the aporose Lichariinae, after the manner of *Thamnopora* from the later Favositidae.

In its general character, therefore, the Craighead fauna is similar to the early Trenton. Thus *Streptelasma* is present in association with *Lambeophyllum.* The Calapoeciidae are represented by *Liopora.* The Heliolitidae are represented by forms of dense structure only; the Halysitidae are present. The Lichenariinae are present, but crenulation of the walls is very marked in the only species. *Tetradium* is present as a massive species only. The differences between the two are also striking; thus *Favistella* is absent; and *Billingsaria,* not *Nyctopora,* is the characteristic nyctoporid.

Robeston Wathen Limestone.

(? Zone of *C. wilsoni* or *Dicranograptus clingani.*)

The next youngest coral fauna in the British Isles seems to be that collected from the Robeston Wathen limestone of S. Wales (Haverfordwest), which, according to Pringle and George (1948, p.30), is developed at about the horizon of the *vulgatus* beds some 90 feet below the top of the Mydrim shales. The assemblage of graptolites in the *vulgatus* beds perhaps suggests the *C. wilsoni* or the *D. clingani* zone of Scotland, but Jones (1936) states that the limestone occurs in the horizon of *Mesograptus multidens,* so that it may be older, perhaps in *C. peltifer* zone. It appears younger than *Nemagraptus gracilis* zone, for the Mydrim limestone at the base of the Mydrim shales has a *Nemagraptus gracilis* assemblage.

The Fron Qy. fauna in the Sedgwick Museum consists of *Streptelasma* cf. *aequisulcatum, Halysites* (2 species) and the heliolitids *Propora hirsuta* (=''*Nicholsonia*'' *megastoma* (McCoy), which also occurs in F_1 at Soida, Estland) and *Propora* sp. nov., with very large tubules. Also from the Robeston Wathen limestone of unspecified locality are the streptelasmid *Brachyelasma* (which occurs in 5a of Norway), a doubtful *Syringaxon* (which, if it could be substantiated, would be the oldest representative of a long-ranging genus), and *Trochiscolithus ? inordinatus* (Lonsdale) a slenderly branching heliolitid with very dense tissues. *Syringophyllum* is represented by a single specimen from Grondre; this calapoeciid genus is not known in N. America, just as *Calapoecia* itself is not known in the British Isles, though the two occur together in Norway (5a).

This fauna, with the occurrence of *Propora* and *Syringophyllum,* has a younger aspect than the Craighead. The absence of Tetradiinae, Stauriidae, Lichenariinae and *Palaeofavosites* is notable.

Coniston Limestone.

(? Zone of *Pleurograptus linearis* or *Dicellograptus anceps.*)

This term ''Coniston Limestone'' originally included the few hundred feet of marine sediment between the Borrowdale Volcanics and the Silurian Stockdale shales in the north of England, but has lately (Eastwood (1935)) been restricted to the lower 100 feet, which Marr (1916) regarded as Caradocian. The corals from the upper 100 feet are mostly from the White Kiesley and equivalent limestones, usually correlated with the *Dicellograptus anceps* zone. King and Williams (1948) have suggested that the Coniston Limestone as at present restricted may represent part of the *D. anceps* zone also, but the evidence is indirect, and most authors have regarded it as older than the *D. anceps* zone and possibly of the zone of *P. linearis.*

From the Museum collections available it does not seem possible to be sure which species of coral are confined to Marr's Caradocian and which to his Ashgillian, with the exception of those from the Ashgillian Kiesley limestone; but, in the main, specimens seem to be from the Sleddale group. *Syringophyllum organum* is abundant, as is *Streptelasma aequisulcatum* and *Halysites.* These three have some resemblance to the Robeston Wathen fauna, as does a wide-tubed species of *Propora.* Other species of Heliolitidae, e.g. *Propora* cf. *goldfussi* (Bill.) (S.M.F. 15224, Helm Gill, Dent) and calical moulds referred to "*Heliolites tubulatus* and *subtubulatus*" are different from those of Robeston Wathen. The most striking difference from Robeston Wathen however is the occurrence of *Palaeofavosites* sp. at Crag Hill, Yorks, and of *P. crassa* at Coniston Waterhead.

Portraine Coral Bed.

The Irish Portraine Coral Bed which possibly is equivalent to the Coniston Limestone (restricted to Sleddale Stage) has an important fauna which, however, is mostly unsectioned. *Propora* cf. *goldfussi* (Bill.) occurs as in the Coniston fauna.

Ashgillian (Zone of *D. anceps,* which includes developments of the dwarf *D. complanatus* fauna (Elles (1937)).

The Ashgillian shelly faunas of North Wales (Denbighshire) have a fair coral fauna which unfortunately has not been investigated by thin section. *Syringophyllum, Palaeofavosites, Halysites, Propora* (with wide tubules) and external moulds of Heliolitidae, some of which suggest *Proheliolites dubius* or *Propora* cf. *goldfussi* (Bill.), are represented in the B.M. collection from Mynydd Fron Frys and nearby.

The Ashgillian Kiesley limestone of the Lakes District contains *Palaeofavosites, Halysites* and *Kiaerophyllum.*

BEAR ISLAND.

(? Zone of *Nemagraptus gracilis.*)

On Bear I., off the north of Norway, *Tetradium syringoporoides* has been found in strata correlated by Holtedahl (1918) with the Black River of N. America, which is reasonably regarded as of *Nemagraptus gracilis* zone. Holtedahl remarks that the associated fauna is purely American, showing no relation to the Middle Ordovician of N.W. Europe.

NORWAY.

Kalstad Limestone (? Zone of *D. clingani*).

In Norway, one of the oldest coral faunas occurs in the Kalstad limestone in Meldalen. Its stratigraphical position is not satisfactorily known. Kiaer (1932) considered its coral fauna compared well with that of the Mjøs limestone in the Oslo district, which is now usually (Størmer, 1945) regarded as between zones 4b δ and 4c α, i.e., the *D. clingani* zone. Vogt (1945) says that it could be equated with the Svattgern rather than with the Holonda of Meldalen; if it correlated with either, the outside limits for its age should be (from stratigraphical relations) the Lower Llanvirn and Middle to Upper Caradoc (*Dicranograptus* shale, i.e. zone of *D. clingani*). Kiaer also compared it with the Craighead limestone which as seen above is possibly *C. peltifer* zone.

The fauna seems very like that of the Trenton of North America. Thus, of the Rugosa, *Streptelasma* occurs, and a cerioid form which Kiaer has placed in *Columnaria,* remarking however that it shows no close resemblance to the N. American '*Columnaria*' and may indeed be a cerioid *Streptelasma.* There is also a curious solitary coral, quite unlike any other Ordovician Rugosa in that it has a rich wide dissepimentarium and very numerous carinate septa, the minor septa being long and leaving only a narrow tabularium in which the major septa extend to the axis (*C. kjerulfi*).

The Halysitidae and Heliolitidae are both represented, the latter by a *Propora* cf. *goldfussi* (Bill.) with resemblances to a form from the Robeston Wathen and Coniston limestones of England. A small cerioid form has been placed doubtfully in *Nyctopora* by Kiaer; however, it could well be *Liopora.* Both these genera are common in the Trenton. A small fasciculate form, much recrystallised, is regarded by Kiaer as *Liopora incerta* (Bill.), but, until its minute structure is better known, we cannot be certain whether it be Syringoporidae, Calapoeciidae or Rhabdocyclidae. No *Lichenaria* or *Tetradium,* so common in the Trenton of N. America, is present; nor *Palaeofavosites* such as characterised the Richmondian and Ashgillian *D. anceps* zone and perhaps also the *P. linearis* zone in N. America and the British Isles.

The Mjøs limestone, which seems to be similar, has the fasciculate "*Liopora incerta,*" the cerioid *Liopora favosa* and *Halysites.*

5a (Zone of *D. anceps*).

The 5a beds of Norway contain a rich coral fauna, especially in the region of Ringerike, where it has been extensively studied. Since 4cα, the black *Tretaspis* shale some distance below these 5a beds, corresponds to the *Pleurograptus linearis* zone, the 5a beds are in all probability of the *D. anceps* zone.

Near Ringerike, at Tyriford, the Rugosa of 5a have been described by Scheffen (1933). It is characterised by Streptelasmidae (*Streptelasma, Brachyelasma* and *Grewingkia*). The Heliolitidae however form a better known element of the fauna, thanks to the work of Kiaer (1899 and 1904) and Lindström (1899). In this family there was an enormous activity in the formation of new genera and species, many of them with delicate skeletal elements in contrast to the dominantly coarse skeletal elements of the earliest Heliolitidae. From Stavnaestangen *Trochiscolithus micraster, Protarea* (*Coccoseris*) *ungerni, Acidolites asteriscus, Diploepora* and *Propora bacillifera* have coarse skeletal elements and are associated with the more delicate *Propora affinis, Proheliolites dubius* and *Plasmoporella convexotabulata* and *vesiculosa.* At Stord the whole fauna has been listed (Kiaer, 1930). In addition to the Streptelasmidae and Heliolitidae recorded above, Calapoeciidae occur with *Liopora, Calapoecia* and *Syringophyllum,* North American and British genera thus occurring here together. The Nyctoporinae are represented by *Nyctopora* cf. *billingsi;* the Halysitidae are present; the Syringoporidae may well be represented by *Reuschia,* and the Favositidae have entered with *Palaeofavosites,* with mural pores at the angles, not the middles, of the walls. The appearance of *Palaeofavosites* seems the interesting point about this fauna, which appears a natural development from that of Robeston Wathen and Coniston, with the American facies represented by *Calapoecia* and *Nyctopora.*

The 5b beds of Norway are variously placed, by indirect correlations, and many writers (Troedsson (1936)) regard them as basal Llandovery, and separated from 5a by disconformity. *Heliolites* has entered as *H. parvistella,* and *Propora* and *Proheliolites* are the dominant Heliolitidae. *Calapoecia* is still present. They will not be further discussed herein.

SWEDEN.

Chasmops Limestone.

(? Zone of *Climacograptus peltifer* or *Dicranograptus clingani*).

The *Chasmops* limestone, according to Thorslund (1940) is developed above the *Nemagraptus gracilis* zone, its upper part being in the *Dicranograptus clingani* zone. The oldest coral in Sweden seems to be in this limestone, *Coelostylis tornquisti* Lindström (in Angelin and Lindström (1880)), from Dalecarlia and Ostrogothia; from the longitudinal section it appears to be a columellate streptelasmid, and its relation to *Dalmanophyllum* Lang and Smith should be investigated.

Kulsberg Limestone (? Zone of *D. clingani*).

The Kulsberg limestone is below the horizon with *Pleurograptus linearis* in the black *Trinucleus* shales, and is correlated by Stφrmer (1945) with possibly the upper *Chasmops* limestone, i.e. with the *D. clingani* zone. Corals are recorded from the Kulsberg limestone, but I am unaware of any figures; it is possibly the lower *Leptaena* limestone of Dalecarlia (Thorslund (1935)).

Upper *Leptaena* Limestone (? Zone of *D. anceps*).

The upper *Leptaena* limestone of Dalecarlia is now known as the Kallholn (= Boda) limestone. The Boda limestone according to Thorslund (1935) contains a hiatus, the lower part having been deposited in the Ordovician above the zone of *Pleurograptus linearis,* and the upper part in Silurian times below the zone of *Monograptus gregarius.* Streptelasmids, *Propora, Proheliolites, Halysites, Syringophyllum* and *Calapoecia* are all recorded from it. Thorslund says these corals seem to come from the upper part of the limestone.

The Southern Lapland Slatdal limestone is coral-bearing and contains (Kulling (1933)) Rugosa, including a fasciculate form ("*Columnaria*" sp. cf. *C. thomi* Hall), together with *Nyctopora* (with 8 long and 8 short septa), *Palaeofavosites, Halysites, Eofletcheria* and the heliolitids *Proheliolites, Propora, Plasmoporella* and *Heliolites,* in *H.* cf. *interstincta.* Kulling equates this with the Norwegian 5b, the *Dalmanites* beds of Skarn, the brachiopod beds of Westergotland and Jemtland, the upper *Leptaena* limestone of Dalarne and the Borkholm (F_2) beds of Estland; and regards it as deposited during an assumed gap in deposition between the Hartfell and Birkhill of Scotland. It seems however identical with the Norwegian 5a fauna from Stord, except for the occurrence of *Heliolites,* the earliest occurrence of which elsewhere is in 5b of Norway.

ESTLAND.

C_2 (? Zone of *Climacograptus peltifer*).

In the Kuckers Stage C_2 of Estland small solitary streptelasmids occur, possibly *Lambeophyllum* with few and rather thin, wavy septa (S.M.A. 3446). This stage is now correlated with the lower *Chasmops* limestone of Sweden and indirectly with the zone of *C. peltifer* (Thorslund 1940).

Wesenberg beds (? Zone of *Pleurograptus linearis*).

The Wesenberg beds, which contain the Trentonian *Protaraea vetusta* Hall (Lindström (1899)) may well be correlated with the Zone of *P. linearis* as suggested by Thorslund (1940).

Lyckholm Beds (? Zone of *Dicellograptus anceps*).

The Lyckholm beds, which are generally correlated with the Norwegian 5a, contain small Rugosa without dissepiments, *Streptelasma*, and *"Columnaria" fascicula*, with *Halysites, Palaeofavosites, Syringophyllum, Calapoecia* and the heliolitids *Trochiscolithus, Protaraea* (*Coccoseris*), *Propora bacillifera* and *Propora hirsuta* (= *"Nicholsonia" megastoma* McCoy of Kiaer). This is indeed a 5a fauna (Kiaer (1899, 1904), Lindström (1899)).

The Borkholm beds, F_2, which are usually correlated with the Norwegian 5b, and which it has been suggested are early Silurian, contain *Heliolites parvistella*, like the 5b beds, the endemic *Palaeoporites*, and *Propora* (Kiaer (1899, 1904), Lindström (1899)). They are not further discussed herein.

ASIA.

Spiti (Central Himalayas) Middle Ordovician (Trenton ?).

Reed (1912) regards a fauna from the Pin Valley containing *Streptelasma* aff. *corniculum, S.* sp. and *? Liopora* sp. as having a pronounced N. American flavour and he correlates it with the Mohawkian, suggesting Trenton.

Aktscha-tau, Siberia (? Caradocian ? Trenton).

Obrutschew (1926) lists *Columnaria alveolata, Halysites* and *Heliolites interstincta* from Aktscha-tau, Siberia, ascribed by Rjabinin to the Caradocian. If this *Heliolites* record is correct this would be the earliest occurrence of the genus, which otherwise first enters in 5b of Scandinavia. Lindström (1882) lists *Calapoecia cribriformis,* and *'Columnaria' alveolata* with a number of Silurian corals from the Middle Tunguska R., and it seems quite likely that these two names here apply to Silurian species, though I have seen no figures.

TASMANIA.

? *D. anceps* zone.

A small fauna from the Queenstown limestone of western Tasmania (Hill and Edwards (1941)), consisting of a streptelasmid, *Tetradium* and the heliolitids *Protaraea* and *Acidolites* with a possible *Alveolites* sp. is regarded as Upper Ordovician, and shows that corals must have been able to migrate from the Arctic to the sub-Antarctic regions during this period. *Plasmoporella, Favosites, Favistella* and *Halysites* from the Chudleigh limestone may also represent an Upper Ordovician fauna, but a Silurian age is possible for these (Hill (1942)).

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APISTOMYIA COLLINI BEZZI (DIPTERA, BLEPHAROCERIDAE) IN NORTH QUEENSLAND.

By I. M. Mackerras and M. J. Mackerras, Queensland Institute of Medical Research, Brisbane.

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(With Plate I.)

Apistomyia collini Bezzi, 1913, was described from a single female collected by the late F. P. Dodd at Kuranda, North Queensland, in September, 1910. So far as we know, it has not been recorded since, although Mr. D. O. Atherton has informed us that he has seen Blepharoceridae in North Queensland streams. The following notes are based on four adults and a considerable series of larvae and pupae, which we collected near Babinda and Cairns in the same general area as the type locality. The stages were associated by the method of dissection described by Tonnoir (1923).

We are indebted to Mr. T. G. Campbell, Division of Economic Entomology, C.S.I.R.O., Canberra, for the loan of specimens of *A. tonnoiri* Tillyard, 1922, for comparison. Specimens of *A. collini* have been lodged in the British Museum (Natural History), the Division of Economic Entomology, C.S.I.R.O., Canberra, and the Institute's collection.

Female.

Mr. Paul Freeman of the British Museum (Natural History) kindly compared one of our specimens with the type in Mr. Collin's collection, and reported that "they are indeed the same . . . ." This sex is to be differentiated most readily from *A. tonnoiri* by the inconspicuous grey dorso-central stripes and barely detectable oblique transverse suture on the scutum, and by the white transverse bands on the abdomen being complete and not interrupted in the mid line. Bezzi's description and Tonnoir's (1930) key are adequate, but the former is not widely available, so a re-description is given.

Length: Body 5 mm.; wing 5.5 mm.; hind leg 13.5 mm.

Head globular. Eyes dark brown, covered with very short, fine, dense hairs; upper zone of enlarged facets about one-third the depth of the lower zone. Frons about three-fifths of head width, greyish black, covered with silvery tomentum, so that the head shows irregular silvery reflections which vary with the incidence of the light. Ocellar triangle raised, prominent, velvety black. Antennae a little longer than the height of the head, ten-segmented, form as in fig. 1; basal segment yellowish to dark brown, silvery at tip, second black, with silvery apical line, remainder black. Face and basal part of the elongate proboscis similarly marked to frons, remainder slender, dark brown; labella black, long and outwardly coiled; palpi very short, one-segmented, black.

Thorax. Scutum covered with velvety, jet black to greyish black tomentum; with narrow grey median and dorso-central lines; and with the following silvery-white markings: a band across the anterior margin, conspicuous patches extending obliquely across the anterior half of the scutum but barely invading the median area between the dorsocentral lines, joining a silvery-white line just above the lateral margin, and a silvery triangle in front of the scutellum, which is black basally, silvery apically (fig. 2); the transverse suture is inconspicuous. Pleurae almost entirely covered with silvery tomentum, but with the sub-alar area brown and dark brown to blackish patches surrounding the anterior and posterior spiracles.

Wings only faintly infuscate (not as darkened as would be inferred from Bezzi's description), but darker between C and Sc; veins dark brown to black; the base of Rs is not detectable, An does not reach the wing margin, and the anal angle is strongly developed, though not as produced as in the ♀ of *A. mackerrasi* Tonnoir, 1930. Halteres with long yellowish brown stem and large black knob.

Legs with coxae and trochanters yellow; femora brownish yellow basally, darkening to blackish distally; remaining segments black. Hind tibia with a pair of strong apical spurs. Claws long and slender, finely serrate on basal two-thirds of inner side.

Abdomen. First segment almost entirely covered with silvery tomentum, but with a narrow black apical transverse patch; second to fifth covered with velvety black tomentum, and with narrow, complete, basal, transverse, silvery white bands, which widen considerably at the sides; sixth and seventh greyish black, rather shiny, and with relatively broader silvery bands than on preceding segments; eighth greyish black; terminal appendages greyish black, obtuse. Venter yellowish brown.

MALE.

Description based on spirit specimens dissected from pupae and compared with similarly dissected females.

Head large, globular; eyes holoptic, with upper zone of enlarged facets larger than lower zone; otherwise similar to ♀, except that mandibles are lacking. *Thorax* with basic pattern of pigment similar to ♀ and differing from dried specimens, as shown in figs. 2, 4, 5. The silvery tomentum cannot be distinguished in the spirit material of either sex. *Wings* and *legs* crumpled; vein An does not reach the margin of the wing, and the anal angle appears to be shaped as in the ♀; spurs are present on the hind tibiae, and the claws bear similar serrations to the ♀. *Abdomen* with the tergal plates produced anteriorly to underlie the posterior edge of the preceding segment (fig. 5); whether this indicates that the silvery bands are interrupted in this sex could not be determined. *Hypopygium* similar to that figured by Tonnoir (1930) for *A. mackerrasi,* and differing from *A. tonnoiri* mainly in the relatively shorter, broader ninth tergite and fused coxites and the proportions of the parts as seen in lateral view (figs. 6, 7).

The ♂ of *A. collini* may be separated from *A. mackerrasi* by the incomplete vein An; it is probably best to distinguish it from *A. tonnoiri* by the hypopygial characters until fully developed specimens have been discovered.

PUPA.

Length 4 to 4.5 mm.; breadth 1.7 to 2 mm.; general form as in fig. 8. Dorsum dark brown, coarsely tuberculate all over, except on head capsule and bases of wing sheaths; indistinct sublateral foveae present on tergites 3 to 7 and traces on 1 and 2. Outer respiratory lamellae vertical, broadly triangular, the anterior taller and with rounded apex, the posterior shorter, truncate. The lateral internal lamella is broadly triangular, with a rounded or pointed shoulder but no projecting basal lobe; the medial is acutely triangular (fig. 9). There is some variation in shape of the lamellae, and the tips appear to have broken off in some specimens, but all the pupae appear to belong to one species.

The pupa is to be distinguished from that of *A. tonnoiri* by the vertical rather than forwardly directed anterior outer respiratory lamellae, and by the shape of the internal lamellae (cf. our fig. 9 and fig. 6C of Tonnoir, 1923).

LARVA.

Length in last instar 5 to 6 mm. Dorsum dark brown, with brownish black markings. Antennae black, the distal segment as long as the basal. Cephalic division finely rugose, with a sublateral pit on each side in its posterior fifth, a conspicuous black pattern anteriorly (fig. 11), a row of scale-like spines between the pits, a short black ridge posterior to these, and a longer black ridge leading to a postero-lateral row of black spines on each side. Cephalic hairs numerous, projecting beyond the anterior and antero-lateral margins of the division. The median divisions have conspicuous black transverse ridges anteriorly and posteriorly, leading to antero- and postero-lateral rows of strong black spines. The anterior edge of each division is marked by a row of broad, brown, scale-like spines, and there are similar but larger spines between these and the anterior black ridge. The posterior section of these divisions is unarmed. The anal division has one transverse black ridge leading to a row of black spines anterior to the lateral appendage; a constriction behind the appendage, with a reduced row of black spines anterior and posterior to it; and a reduced second appendage, which is dark in colour and bears only two to four long, strong hairs. There are a few fine submarginal hairs posteriorly on this division.

The lateral appendages (except the last) are long and conspicuous. and bear long, dense hairs on their dorsal surface and distal margin: the ventral surface and anterior and posterior margins are bare.

Ventral surface creamy brown; suckers normal; ventral gill-tufts long and slender, three directed forward and two backward; anal gills globular, the laterals being larger than the medials (fig. 10). Younger larvae have three gill-filaments (two forward, one backward) and the cephalic division is relatively larger, but are otherwise similar to the older ones.

These larvae differ from Tonnoir's (1923) figures and description of *A. tonnoiri* in the more conspicuous pattern of black pigment, the larger lateral appendages, bare on their ventral surfaces, and the longer, slenderer ventral gill-filaments. In some respects they are closer to his (1930) larva A from Java, but this species has four of the ventral gill-filaments directed anteriorly, one posteriorly.

HABITAT.

The early stages were found on rocks and dead timber, where thin sheets of water were running fast over steep surfaces at the edges of medium and fairly large cataracts. Some of the larvae in Freshwater Creek were attached to deeper ledges of rock, where the rush of water was very powerful and the larvae of *Cnephia strenua* M. & M. (Simuliidae) occurred in considerable numbers. Four adult females were captured flying in the spray at the edge of the falls; no males were seen. These habitats are typical for the genus, and it is curious that no specimens have been found so far in apparently equally suitable situations in southern Queensland.

DISTRIBUTION.

North Queensland: Kuranda, September, *F. P. Dodd* (TYPE ♀); The Cascades, Freshwater Creek, near Cairns, September-October; The Boulders, Babinda Creek, near Babinda, September.

The distribution of the genus is linear but curiously discontinuous, comprising Corsica and Cyprus, the Himalayas, Java, North Queensland (the present species), and New South Wales (*A. tonnoiri* Till. from the Blue Mts. and Mt. Kosciusko). Most of the species seem to be restricted to high country, over 2,000 ft.; but *A. collini* is an exception, in that Kuranda is only 1,080 feet above sea-level and the other localities are much lower.

Related genera have been found in New Zealand and southern New South Wales, and the dispersal of the group presents an interesting problem in zoogeography, on which we do not propose to speculate here.

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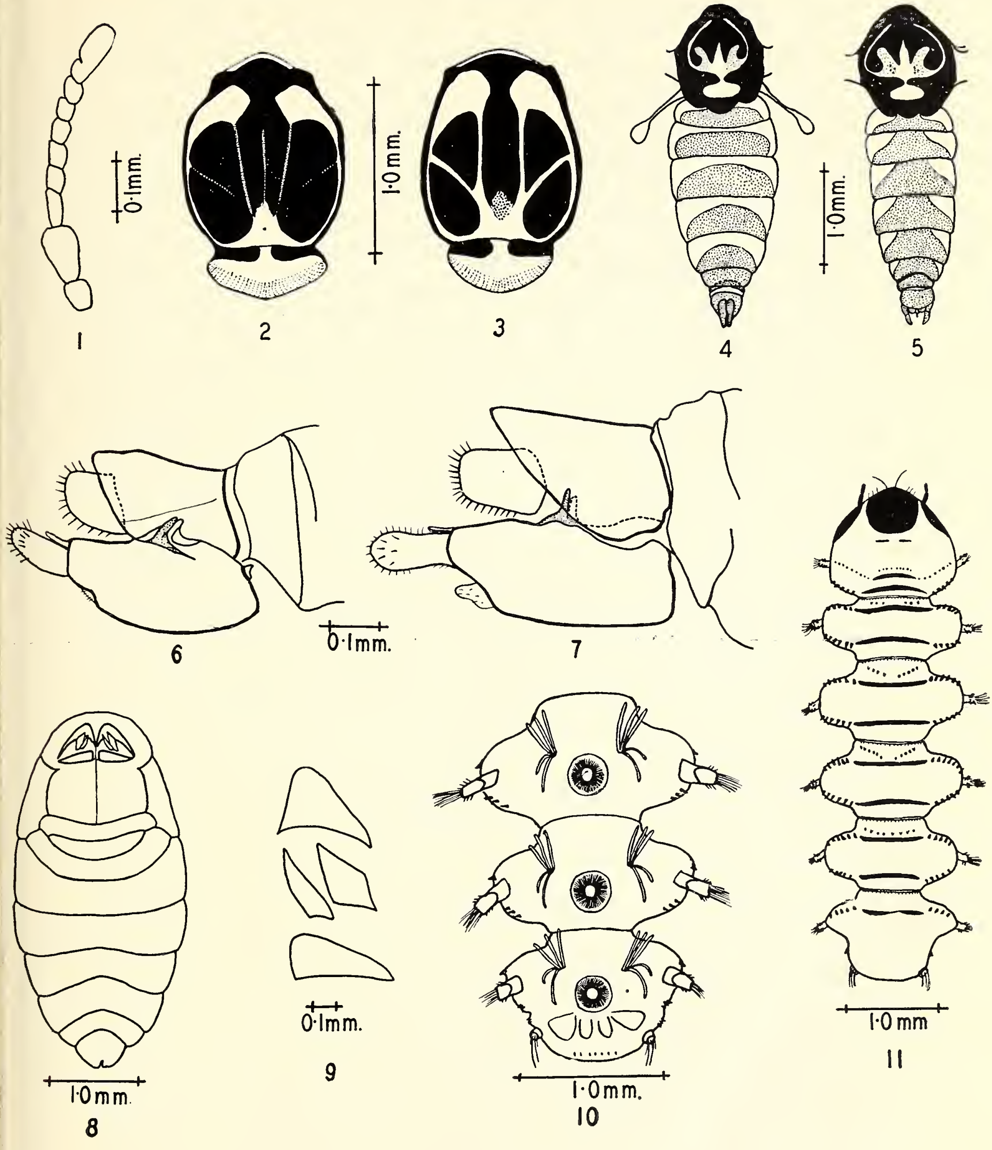

Apistomyia collini Bezzi. 1, antenna of ♀. 2, dorsal view of thorax of ♀. 3, same of *A. tonnoiri* for comparison. 4, dorsal view of ♀ dissected from pupa. 5, same of ♂. 6, hypopygium of ♂, lateral view. 7, same of *A. tonnoiri* for comparison. 8, Dorsal view of pupa. 9, respiratory lamellae of pupa (separated and mounted flat). 10, ventral view of posterior divisions of larva. 11, dorsal view of larva.

TECHNICAL NOTES.

BANDICOOT FOOD.

By Dorothea F. Sandars, Queensland Institute of Medical Research.

In October 1950, a specimen of *Isoodon macrourus torosus* (Ramsay) was found dead on a road in Taringa, Brisbane. This was brought to the Q.I.M.R. Laboratory and subsequently examined for parasites. While examining the gut, it was noted that much of the contents was still in an identifiable condition. It consisted mainly of various insects : the muscular foot region of slugs (these were striped), and a long narrow tail (in 2 pieces) of a small lizard (? *Liolepisma*) were also recovered.

The insects identified by the Entomology Department of the University were :—

Larvae : tenebrionid ; scarabiid ; lepidopteran (2 types) ; coleopteran (2 types) ; one specimen not identified.

Adult Coleoptera : These were all Harpalinae. By comparison with specimens in the Queensland Museum they appeared to be :—*Gnathophanus adelaidae* Cast., *Gnathophanus melanarius* Dej., and one specimen which most closely resembled *Hypharpax latiusculus* Chaud.

Popular public opinion seems to be that bandicoots burrow for roots of plants as food.

Most references to the feeding of bandicoots usually describe their diet as omnivorous. Wood-Jones in " The Mammals of South Australia " says of the bandicoot :—" They possess an untiring energy in searching out and destroying insects." The present case substantiates this. The statement by Troughton in " Furred Animals of Australia " that their diet is a truly mixed one, of insects, vegetable matter, small mammals and probably lizards " is upheld not only by the identification of the contents of the gut of the animal examined, but also by the fact that the bandicoots being kept alive at the Q.I.M.R. as laboratory animals, are fed daily on fresh meat (cut into small pieces) placed on bread. Both are eaten.

The stomach contents of another bandicoot (*Isoodon macrourus torosus*) collected from Indooroopilly, Brisbane on March 9th, 1951, were mainly parts of the fruit of *Passiflora foetida*, the Wild Passion Fruit.

PROCEEDINGS
of the
ROYAL SOCIETY OF QUEENSLAND

VOL. LXII.

C. T. WHITE MEMORIAL SUPPLEMENT

★

The papers that follow are dedicated to the memory of the late CYRIL TENISON WHITE, Government Botanist of Queensland.

★

Cyril Tenison White.

[*Block by courtesy of Queensland Naturalists' Club*

CYRIL TENISON WHITE, 1890-1950.

Cyril Tenison White was born at Kangaroo Point, Brisbane, on 17th August, 1890, the only child of Mr. and Mrs. Henry White. When he was five years old the family moved to Rockhampton but later returned to Brisbane, where he attended the South Brisbane State School. In 1905 he was appointed Pupil Assistant to his maternal grandfather, Frederick Manson Bailey, Colonial Botanist of Queensland, then in his seventy-eighth year. Some of his early duties were the copying of letters for his grandfather, the collecting and despatch of plants of all kinds to overseas specialists and the drawing of nearly a thousand sketches for Bailey's *Comprehensive Catalogue of Queensland Plants.* These drawings, crude as they appear to be, give an unexpectedly accurate impression of the plants and are far more informative than many illustrations of higher artistic merit. This early work laid the foundations of White's extraordinary knowledge of plants.

F. M. Bailey died in 1915 and was succeeded by his son, John Frederick Bailey, who had been curator of the Botanic Gardens since 1905. J. F. Bailey held the dual position of Government Botanist and Curator of the Botanic Gardens until 1917, when he accepted the position of Director of the Adelaide Botanic Gardens. White then became Acting Government Botanist, and in 1918 was appointed Government Botanist, a position he held until his death.

The duties of Government Botanist have always included a large amount of advisory work for the Department of Agriculture and Stock as well as for the general public, and White's knowledge of cultivated plants was freely called upon. At first White carried on almost alone, but in 1919 W. D. Francis was appointed assistant, and it was not until the 1930's that other botanists joined his staff. He was Lecturer in Forest Botany in the University of Queensland and had been a member of its Faculty of Agriculture.

White had a wide interest in science, horticulture, and the conservation of nature, and took an active part in many societies. He served on the council of the Royal Society of Queensland from 1909 until 1911 and, except for occasional years, from 1918 to 1938; he was honorary librarian in 1909-11 and president in 1921. He took a special interest in the Queensland Naturalists' Club and he served on its council from 1910 until his death, except for the single year 1939, when he was in England; he was honorary excursion secretary in 1912, honorary secretary and treasurer in 1913, honorary secretary in 1914-7, honorary editor from 1920 to 1938 and in 1940 (sharing the position with A. H. Chisholm in 1920-22), and president in 1918, 1923, and 1943. He was a regular attendant at excursions (which he often led) and meetings, and stimulated interest in young and old alike. From 1922 to 1927 he was local honorary secretary to the Australasian Association for the Advancement of Science, and he served on the councils of the Queensland Horticultural Society, Royal Geographical Society of Australasia (Queensland Branch), Queensland Orchid Society, Professional Officers' Association (of all of which he had been president), and the National Parks Association of Queensland. He had been a Fellow of the Linnaean Society of London, but resigned his membership some years ago. He was awarded the Mueller Medal for distinguished services to Australian Natural History in 1946 and was granted the honorary degree of Master of Science by the University of Queensland in 1948.

White loved plants and had an amazing knowledge of the flora of Australia, New Caledonia, and New Guinea, and of garden plants. He made many private collecting trips in unofficial time. He collected in all Australian States except the Northern Territory, in Papua (in 1918, chiefly in the neighbourhood of Yule Island, Port Moresby and the Astrolabe Range), in New Caledonia in 1923, England in 1939, the Territory of New Guinea in 1944 when he acted as Instructor to Army Forestry Units, and in 1945, and he assisted in a forestry survey of the Solomon Islands in 1945. His numbered collections exceed 13,000, but the specimens collected before his Papuan trip of 1918 were not numbered. The collections in the Territory of New Guinea carry mostly N.G.F. (New Guinea Forests) numbers and the collections made with F. S. Walker in the Solomon Islands form a series preceded by the letters B.S.I.P. Some small collections made in Queensland also have different numberings. His collections greatly expanded the Queensland Herbarium started by F. M. Bailey, and his duplicates are widely distributed. Early in 1939 he went to England as Australian Liaison Officer at the Royal Botanic Gardens, Kew, but war conditions forced him to return to Brisbane before the end of the year.

In spite of the calls made on his time by an ever-increasing amount of routine matters, White made a very large contribution to the knowledge of the floras of Queensland, north-eastern New South Wales, New Caledonia, New Guinea, and the Solomon Islands. He had an extensive knowledge of all groups of vascular plants, but he was particularly interested in woody plants. Some of his papers suggest that he was chiefly interested in the discovery and recording of what was new or unusual; this may have been the case in his younger days, but a great part of his published reports of plants new to Queensland or of new species was based on fairly extensive studies of all available material of the genera concerned. He worked rapidly but carefully and was always eager to send material to specialists for detailed study.

His earliest publications were in the *Queensland Naturalist*, and to this journal he made nearly fifty contributions, chiefly brief accounts of the vegetation of localities visited or plants collected during the excursions of the Queensland Naturalists' Club, but also an illustrated account of twenty-three species of *Eucalyptus* found in the neighbourhood of Brisbane and keys to twenty species of *Acacia* from the same area. By far the greatest number of articles with which his name is associated appeared in the *Queensland Agricultural Journal*. These are mostly short and often semipopular in nature; nearly a hundred deal with weeds or plants suspected poisonous to stock or humans, and a few of these were written with J. F. Bailey, F. Smith, or E. H. Gurney; forty others, with W. D. Francis as co-author, are well-illustrated accounts of Queensland trees that were afterwards used by Francis in his *Australian Rain-forest Trees*. The bulk of his systematic work on Queensland plants appeared under the title of "Contributions to the Queensland Flora"; the earlier ones, with J. F. Bailey or W. D. Francis as co-author, appeared as Botany Bulletins of the Queensland Department of Agriculture and Stock, but from 1922 onwards they appeared in the *Proceedings of the Royal Society of Queensland,* with W. D. Francis as co-author of the earlier of these. Another large paper is "Ligneous plants collected for the Arnold Arboretum in North Queensland by S. F. Kajewski in 1929," published as *Contributions from the Arnold Arboretum No.* 4. Most of his earlier work on the flora of New Guinea was published in the *Proceedings of the Royal Society of Queensland* (that on the collections of Lane-Poole with W. D. Francis), but his later work on this area, on New Caledonia, and the Solomon Islands appeared in the *Journal of the Arnold Arboretum.* (A preliminary account of his collections from the Solomon Islands was given by F. S. Walker in his report: "The Forests of the British Solomon Islands Protectorate"; London, 1948.) Three biographical papers give an interesting account of early Queensland botany and incidentally of his own background. The "Tryon Memorial Lecture," in 1945, dealt with H. Tryon, the others, in 1945 and 1950, dealt with F. M. Bailey and his family.

White wrote two useful books. "An elementary textbook of Australian forest botany" was published in 1922, and a second edition appeared in 1925. Both editions are marked "Vol. 1"; a second volume was planned but not written. "Principles of Botany for Queensland Farmers" was published in book form in 1941 but had previously appeared in seven parts in the *Queensland Agricultural Journal* in 1936-37. Both are textbooks for botany in their respective fields, with Australian examples, and both give good general accounts of Queensland vegetation.

His kindliness, tolerance, good humour, and enthusiasm endeared "C.T." to a large number of friends and acquaintances from many walks of life. He was always ready and willing to give advice, but rarely offered it unless asked; he never forced his opinions on anybody and his kindliness was often imposed on. He was a skilful raconteur, and his wealth of anecdote enlivened many a lunch period in the herbarium and camp-fire gathering. He was a link between the old school of naturalists and the modern one trending to specialization and was able to adjust himself to the change.

Almost his only hobbies were his home and his garden, and his wife and two daughters shared his interest in natural history. He was seriously ill for some months in 1947, but recovered sufficiently to carry on most of his usual activities at a reduced tempo. A heart attack on the eve of his sixtieth birthday meant the loss of a lovable man and an outstanding scientist who, on the day of his death, was preparing for a collecting trip to North Queensland.

The following bibliography is based on a list of publications prepared by Mr. J. Clancy. In addition to the works listed, notes on a variety of plants appeared in many parts of the *Queensland Agricultural Journal* in. 1926-46 (new series, vols. 26-63) under the heading "Answers to Correspondents." White's name has been also associated elsewhere in the same journal with the identification of plants and remarks thereon.

S. T. BLAKE,
Botanic Museum and Herbarium,
Botanic Gardens, Brisbane.

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Weeds of Queensland. No. 34. A "rattle pod" *Crotolaria striata.* Queensl. Agric. J. n.s. **20** : 236-239.

Sour grass or yellow grass. Queensl. Agric. J. n.s. **20** : 46.

A thin-shelled variety of the Queensland nut (*Macadamia ternifolia*). Queensl. Agric. J. n.s. **20** : 93-95.

Queensland trees. No. 17. The black apple or black plum (*Sideroxylon australe*). Queensl. Agric. J. n.s. **19** : 78-80. (With W. D. Francis.)

Queensland trees. [No. 18.] Southern ghittoe (*Halfordia drupifera*). Queensl. Agric. J. n.s. **19** : 197-199. (With W. D. Francis.)

Queensland trees. No. 19. The scrub beefwood. Queensl. Agric. J. n.s. **19** : 304-305, 415. (With W. D. Francis.)

Queensland trees. No. 20. [The rose-leaf or pink marara, *Ackama paniculata.*] Queensl. Agric. J. n.s. **19** : 409-441. (With W. D. Francis.)

Queensland trees. No. 21. The maiden's blush. Queensl. Agric. J. n.s. **19** : 513-515. (With W. D. Francis.)

Queensland trees. No. 22. [The bolly gum, *Litsea reticulata.*] Queensl. Agric. J. n.s. **20** : 46-48. (With W. D. Francis.)

Queensland trees. No. 23. The corduroy tamarind. Queensl. Agric. J. n.s. **20** : 90-92, (With W. D. Francis.)

Queensland trees. No. 24. The blue quandong. Queensl. Agric. J. n.s. **20** : 175-177. (With W. D. Francis.)

Queensland trees. No. 25. Pepperberry tree. Queensl. Agric. J. n.s. **20** : 362-364. (With W. D. Francis.)

Queensland trees. [No. 26. Ribbonwood, *Euroschinus falcatus.*] Queensl. Agric. J. n.s. **20** : 434-436. (With W. D. Francis.)

1924.

On a new species of *Melaleuca* (family Myrtaceae) from southern Queensland. Proc. Roy. Soc. Queensl. **36** : 41-43. (With E. Cheel.)

The eucalypts or gum trees of the Brisbane district. Queensl. Nat. **4** : 67-72.

The eucalypts or gum trees of the Brisbane district, II. Queensl. Nat. **4** : 109-112.

Flora of Moreton Island. (Report on the Easter encampment (1924) of the Queensland Naturalists' Club at Cowan Cowan.) Queensl. Nat. **4** . 86-91.

Weeds of Queensland. No. 35. Bitter bark, native cinchona or quinine (*Alstonia constricta*). Queensl. Agric. J. n.s. **21** : 252-253.

Weeds of Queensland. No. 36. Bluetop heliotrope (*Heliotropium anchusaefolium*). Queensl. Agric. J. n.s. **21** : 284-285.

Notes on two weed pests. Queensl. Agric. J. n.s. **21** : 286.

Wattle bark : The possibilities of its cultivation in Queensland. Queensl. Agric. J. n.s. **21** : 423-425.

The southern olive, *Notelaea longifolia* var. *velutina.* A native plant harbouring fruit-fly larvae in the Stanthorpe district. Queensl. Agric. J. n.s. **22** : 240-241.

Possibilities of camphor cultivation in Queensland. Queensl. Agric. J. n.s. **22** : 308.

Two valuable fodder trees. Queensl. Agric. J. n.s. **22** : 352-356.

The native bryony (*Bryonia laciniosa*). A poisonous plant. Queensl. Agric. J. n.s. **22** : 442-444.

Queensland trees. [No. **28**. South Queensland kauri, *Agathis robusta*] Queensl. Agric. J. n.s. **21** : 34-36. (With W. D. Francis.)

Queensland trees. [No. **29**. Sour cherry, *Eugenia corynantha.*] Queensl. Agric. J. n.s. **21** : 281-283. (With W. D. Francis.)

Queensland trees. No. 30. [*Cryptocarya patentinervis.*] Queensl. Agric. J. n.s. **21** : 437-439. (With W. D. Francis.)

Queensland trees. No. 31. [Bunya pine, *Araucaria Bidwillii* ; a bolly gum, *Beilschmiedia elliptica.*] Queensl. Agric. J. n.s. **22** : 26-27, 32. (With W. D. Francis.)

Queensland trees. [No. 32. *Sideroxylon pohlmanianum*.] Queensl. Agric. J. n.s. **22** : 65-67. (With W. D. Francis.)

Queensland trees. [No. 33. *Lucuma amorphosperma*.] Queensl. Agric. J. n.s. **22** : 238-239. (With W. D. Francis.)

Queensland trees. [No. 34. *Endiandra compressa*.] Queensl. Agric. J. n.s. **22**: 308-310. (With W. D. Francis.)

Queensland trees. [No. 35. Broad-leaved leopard tree, *Flindersia collina*.] Queensl. Agric. J. n.s. **22** : 356-358. (With W. D. Francis.)

Queensland trees. [No. 36. Native tamarind, *Diploglottis cunninghamii*.] Queensl. Agric. J. n.s. **22** : 444-446. (With W. D. Francis.)

1925.

An elementary textbook of Australian forest botany, vol. 1. 2nd ed. Govt. Printer, Sydney.

The eucalypts or gum trees of the Brisbane district, III. Queensl. Nat. **5** : 12-16.

The eucalypts or gum trees of the Brisbane district, IV. Queensl. Nat. **5** : 43-45.

Fruit of *Acronychia imperforata*—A " wild orange." [Remarks on a note by J. H. Schmeider.] Queensl. Nat. **5** : 48.

Weeds of Queensland. No. 37. Devil's claw (*Martynia lutea*). Queensland Agric. J. n.s. **23** : 96-97.

Weeds of Queensland. No. 38. *Bassia birchii* (a " chinese burr "). Queensl. Agric. J. n.s. **23** : 200-201.

Weeds of Queensland. No. 39. Narrow-leaved sage (*Salvia lancifolia*). Queensl. Agric. J. n.s. **23** : 417-418.

Weeds of Queensland. No. 40. American dog weed (*Verbescina encelioides*). Queensl. Agric. J. n.s. **23** : 520-521.

Vinca rosea—A reputed cure for diabetes. Queensl. Agric. J. n.s. **23** : 143-144.

Queensland forests and forest trees. Queensl. Agric. J. n.s. **24** : 124-128.

Queensland trees. [No. 37. Scrub wilga, *Geijera salicifolia*.] Queensl. Agric. J. n.s. **23** : 146-147. (With W. D. Francis.)

Queensland trees. [No. 38. Deep yellow-wood, *Rhodosphaera rhodanthema*.] Queensl. Agric. J. n.s. **23** : 202-204. (With W. D. Francis.)

Queensland trees. [No. 39. *Cryptocarya foveolata*.] Queensl. Agric. J. n.s. **23**: 334-335. (With W. D. Francis.)

Queensland trees. [No. 40. Australian olive, *Olea paniculata*.] Queensl. Agric. J. n.s. **24** : 438-440. (With W. D. Francis.)

1926.

Contributions to the Queensland flora, No. 3. Proc. Roy. Soc. Queensl. **37** : 152-167. (With W. D. Francis.)

The eucalypts or gum trees of the Brisbane district, V. Queensl. Nat. **5** : 51-53.

The eucalypts or gum trees of the Brisbane district, VI. Queensl. Nat. **5** : 94-96.

A previously undescribed *Dodonaea* from south-eastern Queensland. Queensl. Nat. **6** : 13-14.

Report on the botany of the Queensland Naturalists' Club Excursion to Elimbah, 11th-13th Sept., 1926. Queensl. Nat. **6** : 14-15.

On a small collection of plants from the Rigo district, Papua (British New Guinea). Proc. Linn. Soc. N. S. Wales **51** : 296-298.

A new species of *Diplospora* from southern Queensland. J. Bot. **64** : 216-217.

The genus *Sonneratia* in Queensland. J. Bot. **64** : 217-218.

A variety of *Ceriops tagal* C. B. Rob. (*C. candolleana* W. & A.). J. Bot. **64** : 220-221.

Ligneous plants collected in New Caledonia by C. T. White in 1923. J. Arnold Arb. **7** : 74-103. (With E. H. Wilson and A. Guillaumin.)

A new species of *Paramignya* of Papua with notes on two other Papuan Rutaceae. J. Arnold Arb. **7** : 231-233.

An interesting plant, *Gomphrena leontopodioides*. Queensl. Agric. J. n.s. **25** : 270 271.

Destruction of the khaki weed. Queensl. Agric. J. n.s. **25** : 512.

Weeds of Queensland. No. 41. Rivina (*Rivina laevis*). Queensl. Agric. J. n.s. **25** : 274-275.

Weeds of Queensland. No. 42. Milky cotton bush (*Asclepias curassavica*). Queensl. Agric. J. n.s. **26** : 125-127.

1927.

Plants collected in Papua by C. E. Lane-Poole. Proc. Roy. Soc. Queensl. **38** : 225-261. (With W. D. Francis.)

A previously undescribed species of *Maniltoa* from Papua. J. Arnold Arb. **8** : 130.

Two Papuan species of *Ardisia*. J. Bot. **65** : 248.

Rivina (*Rivina laevis*). Queensl. Agric. J. n.s. **27** : 130.

Vinca rosea—A reputed cure for diabetes. Queensl. Agric. J. n.s. **28** : 354-355.

Queensland trees. [No. 41.] The tallow-wood (*Eucalyptus microcorys*). Queensl. Agric. J. n.s. **28** : 46-48.

1928.

Plants collected in the Mandated Territory of New Guinea by C. E. Lane-Poole. Proc. Roy. Soc. Queensl. **39** : 61-70. (With W. D. Francis.)

The eucalypts or gum trees of the Brisbane district, VII. Queensl. Nat. **6** : 78-82.

Recent botanical work in the Pacific. Queensl. Nat. **6** : 85-88.

Weeds of Queensland. Button weed or button mallow (*Modiola caroliniana*). Queensl. Agric. J. n.s. **30** : 598-599.

1929.

Contributions to the Queensland flora, No. 4. Proc. Roy. Soc. Queensl. **41** : 139-143. (With W. D. Francis.)

The eucalypts or gum trees of the Brisbane district, VIII. Queensl. Nat. **7** : 36-39.

Ligneous plants collected in the Territory of Papua (British New Guinea) in 1925-26 by L. J. Brass. J. Arnold Arb. **10** : 197-274.

William Vincent Fitzgerald. J. Bot. **67** : 309.

Weeds of Queensland. The correct botanical identity of the *Lantana* naturalised in Queensland. Queensl. Agric. J. n.s. **31** : 294-296.

Weeds of Queensland. *Cassia laevigata* Willd. (an arsenic bush). Queensl. Agric. J. n.s. **31** : 352-353.

Queensland weeds. Twin leaf (*Zygophyllum apiculatum*) ; *Solanum auriculatum*—a "wild tobacco." Queensl. Agric. J. n.s. **32** : 194-197.

1930.

Two interesting Queensland eucalypts. Proc. Roy. Soc. Queensl. **42** : 82-85. (With W. F. Blakely).

The margosa tree and its allies. Queensl. Agric. J. n.s. **34** : 17.

Weeds of Queensland. Bindweed (*Convolvulus arvensis*). Queensl. Agric. J. **33** : 322-323.

Note on *Darlingia spectatissima* F.v.Muell. with description of a new variety. J. Arnold Arb. **11** : 231.

Queensland Vegetation in Handbook for Queensland. Austral. Ass. Adv. Sci., Brisbane Meeting, 1930.

A new genus of Proteaceae from North Queensland. Kew Bull. **1930** : 234-235.

1931.

Two previously undescribed Queensland Myrtaceae. Proc. Roy. Soc. Queensl. **43** : 15-16.

Herbert Bennett Williamson. J. Bot. **69** : 172.

1932.

Two previously undescribed Rutaceae from south-eastern Queensland. Proc. Roy. Soc. Queensl. **43** : 46-48.

Gustav Weindorfer. J. Bot. **70** : 261.

A previously undescribed Papuan Dipterocarp. Proc. Roy. Soc. Queensl. **43** : 49.

Botanising in Tasmania. Queensl. Nat. **8** : 38-40.

The eucalypts or gum trees of the Brisbane district. [IX.] Queensl. Nat. **8** : 52-54.

The occurrence of the genus *Aceratium* (Elaeocarpaceae) in Australia. Kew Bull. **1932** : 42.

1933.

The genus *Pleiogynium* in Papua. Proc. Roy. Soc. Queensl. **45** : 27-28.

The eucalypts or gum trees of the Brisbane district. [X.] Queensl. Nat. **8** : 80-81.

Ligneous plants collected for the Arnold Arboretum in north Queensland by S. F. Kajewski in 1929. Contrib. Arnold Arb. **4**. 113 pp., 9 pl.

A plant poisonous to live stock. Queensl. Agric. J. n.s. **40** : 143-144. (With J. A. Rudd.)

The noogoora burr (*Xanthium pungens*). A weed poisonous to livestock. Queensl. Agric. J. n.s. **40** : 413.

Nomenclature of some Australian and Philippine Island plants. Kew Bull. **1933** : 45-46.

1934.

Botany, Mount Edwards and district. (A) General. Queensl. Nat. **9** : 36-37.

The eucalypts or gum trees of the Brisbane district. [XI.] Queensl. Nat. **9** : 8-9.

The eucalypts or gum trees of the Brisbane district. [XII.] Queensl. Nat. **9** : 31-32.

Dendrobium (§ *Rhizobium*) *Grimesii* White & Summerhayes. Kew Bull. **1934** : 106. (With V. S. Summerhayes.)

Queensland grasses. Queensl. Agric. J. n.s. **41** : 54-58.

Vinca rosea. A reputed cure for diabetes. Queensl. Agric. J. n.s. **41** : 598-600.

Queensland weeds. Blue weed or paterson's curse (*Echium plantagineum*). Queensl. Agric. J. n.s. **41** : 304-305.

Queensland weeds. Mist flower (*Eupatorium riparium*). Queensl. Agric. J. n.s. **41** : 519-521.

Queensland weeds. Gomphrena weed (*Gomphrena decumbens*). Queensl. Agric. J. n.s. **42** : 83-84.

Queensland weeds. Nut grass (*Cyperus rotundus*). Sour grass or yellow grass (*Paspalum conjugatum*). Queensl. Agric. J. n.s. **42** : 360-363.

Queensland weeds. Khaki weed (*Alternanthera repens*). Queensl. Agric. J. n.s. **42** : 583-584.

Thomas Lane Bancroft. J. Bot. **72** : 141-142.

1935.

Notes on the genus *Ptychosperma* in Queensland. Proc. Roy. Soc. Queensl. **46** : 80-82.

The structure and classification of Queensland orchids. Queensl. Nat. **9** : 55-61.

The common bracken (*Pteridium aquilinum*). Queensl. Agric. J. n.s. **43** : 150-151.

Two trees of the genus *Dysoxylum* in North Queensland. North Queensl. Nat. **3** : 34-36.

Lantana (*Lantana camara*) and poison peach (*Trema aspera*). Their effects on stock. Queensl. Agric. J. n.s. **43** : 369-373. (With K. S. McIntosh.)

Queensland weeds. Indian jujube or china apple (*Zizyphus mauritiana*). Queensl. Agric. J. n.s. **44** : 98-99.

Weeds of Queensland. Creeping knapweed (*Centaurea repens*). Queensl. Agric. J. n.s. **44** : 702-703.

1936.

Contribution to the Queensland flora, No. 5. Proc. Roy. Soc. Queensl. **47** : 51-84.

The eucalypts or gum trees of the Brisbane district. [XIII.] Queensl. Nat. **9** : 114-115.

Queensland weeds. Tridax daisy or tridax. (*Tridax procumbens*, family Compositae) Queensl. Agric. J. n.s. **45** : 258-259.

Groundsel bush or tree groundsel (*Baccharis halimifolia*). Queensl. Agric. J. n.s. **45** : 575-576.

Clovers and trefoils in Queensland. Queensl. Agric. J. n.s. **46** : 51-54.

Principles of botany for Queensland Farmers. Queensl. Agric. J. n.s. **46** : 196-228, 358-391, 481-505, 602-632, 747-766.

1937.

Principles of botany for Queensland farmers. Queensl. Agric. J. n.s. **47**: 17-48, 154-180.

Queensland weeds. Johnson grass and wild sorghum. Queensl. Agric. J. n.s. **47**: 365-368.

Is button grass poisonous to sheep ? Queensl. Agric. J. n.s. **47** : 502.

Pitted blue grass. A pest in coastal pastures. Queensl. Agric. J. n.s. **48** : 70.

Hexham scent. Queensl. Agric. J. n.s. **48** : 430.

Two new dendrobs for north Queensland. Queensl. Nat. **10** : 25-26. (With H. M. R. Rupp.)

The Australian species of *Rhodamnia*. Blumea Suppl. **1** : 214-218.

1938.

The eucalypts or gum trees of the Brisbane district. [XIV.] Queensl. Nat. **10** : 72-73.

Queensland weeds. *Anoda cristata*. Queensl. Agric. J. n.s. **49** : 332-333.

Queensland weeds. Shrubby or upright mist flower (*Eupatorium adenophorum*). Queensl. Agric. J. n.s. **50** : 8-9.

The varieties of guinea grass cultivated in Queensland. Queensl. Agric. J. n.s. **49** : 110-112.

Bindweed—A serious weed pest. Queensl. Agric. J. n.s. **50** : 7.

Shrubby or upright mist flower. Queensl. Agric. J. n.s. **50** : 83.

Two weeds poisonous to stock. Queensl. Agric. J. n.s. **50** : 217.

A cause of shivers or staggers in stock. Queensl. Agric. J. n.s. **50** : 533.

Melilot or Hexham scent. Queensl. Agric. J. n.s. **50** : 661-662.

Principles of botany for Queensland farmers. Govt. Printer, Brisbane. 232 pp., 102 pl. (Previously published in parts in 1936-7 in Queensl. Agric. J.)

Ferns of Mt. Spurgeon, North Queensland. Vict. Nat. **54**: 147-151. (With D. A. Goy).

John Frederick Bailey. J. Bot. **76** : 307.

1939.

Contributions to the Queensland Flora, No. 6. Proc. Roy. Soc. Queensl. **50** : 66-87.

Solanum hispidum Pers. : its distribution and synonymy. Kew Bull. **1939** : 666-668.

Wild sunflower—A poisonous plant. Queensl. Agric. J. n.s. **51** : 97-98.

Hoary cress (*Lepidium draba*). A possible serious weed pest in Queensland. Queensl. Agric. J. n.s. **52** : 658-661.

1940.

A new type of sundew from north Queensland. Vict. Nat. **57** : 94-95.

A new *Dendrobium* from New Guinea. Austr. Orchid Rev. **5** : 74-75.

A history of Australian orchids (in part). Austr. Orchid Rev. **5** : 89.

1941.

A new genus of Flacourtiaceae (Pangieae-Hydnocarpinae) from tropical Queensland. J. Arnold Arb. **22** : 143-144.

Red-flowered lotus or bird's foot trefoil (*Lotus coccineus*). Queensl. Agric. J. n.s. **55** : 297-299. (With E. H. Gurney.)

Shade and ornamental trees and shrubs for the pig farm. Queensl. Agric. J. n.s. **55** : 300-302. (With E. J. Sheldon.)

Noxious weeds. Queensl. Agric. J. n.s. **56** : 332-336.

Myoporum acuminatum (strychnine bush)—A plant poisonous to stock. Queensl. Agric. J. n.s. **56** : 124-125.

Myoporum acuminatum : A plant poisonous to stock. Austr. Vet. J. **17** : 104-105. (With J. Legg.)

A new variety of *Dendrobium* from N. Queensland. Austr. Orchid Rev. **6** : 53.

Queensland Pasture Plants. Pamphlet No. 85. Queensl. Dept. Agric. & Stock. 29 pp. (With S. L. Everist and C. W. Winders.)

1942.

Contributions to the Queensland Flora, No. 7. Proc. Roy. Soc. Queensl. **53** : 201-228.

A rare lycopod from the Lamington National Park, S.E. Queensland. Queensl. Nat. **12** : 32-33.

Some Papuan Myrtaceae. J. Arnold Arb. **23** : 79-92.

The genus *Dendrobium* in Australia. Austr. Orchid Rev. **7** : 4-7.

1943.

On two interesting species of *Marsdenia* (family Asclepiadaceae). Queensl. Nat. **12** : 54-55.

Has *Dendrobium ophioglossum* been rediscovered ? Austr. Orchid Rev. **8** : 19.

The genus *Dendrobium* in New Guinea and the Solomon Islands. Austr. Orchid Rev. **8** : 62-63.

1944.

Contributions to the Queensland Flora, No. 8. Proc. Roy. Soc. Queensl. **55** : 59-83.

The algaroba bean or mesquite as a pest plant. Queensl. Agric. J. n.s. **58** : 360-361.

Gomphrena weed. Queensl. Agric. J. n.s. **58** : 179-180.

The sword bean (*Canavalia gladiata*). Queensl. Agric. J. n.s. **58** : 307.

Crofton weed, a serious pest. Queensl. Agric. J. n.s. **59** : 154-155.

New Guinea timbers. Queensl. Agric. J. n.s. **59** : 278-282.

Giant sensitive plant. A very serious weed pest in North Queensland. Queensl. Agric. J. n.s. **59** : 341-342.

Cretan weed. Queensl. Agric. J. n.s. **59** : 343.

A new variety of *Dendrobium phalaenopsis* (Fitzg.). Austr. Orchid Rev. **9** : 35.

1945.

Tryon memorial lecture : Henry Tryon—First Hon. Secretary, Royal Society of Queensland, and his place in Queensland Science. Proc. Roy. Soc. Queensl. **56** : 77-80.

Wattles or Acacias of the Brisbane district. Queensl. Nat. **12** : 107-113.

Chinese spinach. A useful summer vegetable. Queensl. Agric. J. n.s. **60** : 83-84.

Bulbous oat grass or onion couch, a possible weed pest. Queensl. Agric. J. n.s. **60** : 154.

Shade and shelter plants for the pig farm. Queensl. Agric. J. n.s. **60** : 226-227. (With E. J. Shelton.)

Chicory—A weed pest often confused with skeleton weed. Queensl. Agric. J. n.s. **60** : 352.

The Bailey family and its place in the botanical history of Australia. J. Hist. Soc. Queensl. **3** : 362-368.

Flora of Melanesia. Queensl. Geogr. J. n.s. **49** : 64-67.

1946.

Contributions to the Queensland flora, No. 9. Proc. Roy. Soc. Queensl. **57** : 21-36.

An important contribution to our knowledge of Dutch New Guinea (Fragmenta Papuana (Observations of a naturalist in Netherlands New Guinea) by H. J. Lam ; a review and commentary). Queensl. Nat. **13** : 13-18.

St. Barnaby's Thistle. Queensl. Agric. J. n.s. **62** : 271-272.

Dr. Eugen Hirschfeld : An appreciation. Queensl. Agric. J. n.s. **63** : 117-118.

The devil's fig (*Solanum torvum*). Queensl. Agric. J. n.s. **63** : 280-281.

The Australian species of *Antirhea*, and a new name for a Cuban species. J. Arnold Arb. **27** : 121-122.

Papuodendron, a new genus of arborescent Malvaceae from New Guinea. J. Arnold Arb. **27** : 272-274.

A new species of *Longetia* : the botanical identity of a " pink cherry " of Dorrigo timber-getters. Proc. Linn. Soc. N. S. Wales **71** : 236-238. (With W. A. W. de Beuzeville.)

Botanizing in the British Solomon Islands. Austr. J. Sci. **9** : 62-64.

1947.

Notes on two species of *Araucaria* in New Guinea and a proposed new section of the genus. J. Arnold Arb. **28** : 259-260.

1948.

Three species of *Endiandra* (family Lauraceae) from eastern Australia. Proc. Roy. Soc. Queensl. **59** : 151-152.

A new species of *Austrobaileya* (Austrobaileyaceae) from Australia. J. Arnold Arb. **29** : 255-256.

1949.

The genus *Embothrium* Forst. (family Proteaceae) in Australia. Proc. Roy. Soc. Queensl. **60** : 43-44.

Finschia—A genus of " nut " trees of the south-west Pacific. Pacific Sci. **3** : 187-194.

Star thistle—a new weed pest. Queensl. Agric. J. n.s. **69** : 84-85.

Wild cottons—declared noxious weeds. Queensl Agric. J. n.s. **69** : 143-145.

Weir vine—a declared noxious plant. Queensl. Agric. J. n.s. **69** : 143-145.

1950.

Additions to the flora of Arnhem Land. Proc. Roy. Soc. Queensl. **61** : 55-58.

F. M. Bailey : His life and work. Proc. Roy. Soc. Queensl. **61** : 105-114.

Ligneous plants from the Solomon Islands (and New Guinea). J. Arnold Arb. **31** : 81-116.

Report on the botany of the Mt. Alford excursion. Queensl. Nat. **14** : 35-36.

1951.

Some noteworthy Myrtaceae from the Moluccas, New Guinea and the Solomon Islands. J. Arnold Arb. **32** : 139-149.

A previously undescribed *Pomaderris* from south-east Queensland. Queensl. Nat. **14** : 48.

REDUCTIONS IN ELAEOCARPUS.

By E. D. Merrill, Arnold Arboretum, Harvard University.

(Issued separately, 15th August, 1952.)

SUMMARY.

90 published names under *Elaeocarpus* are reduced to synonymy.

Elaeocarpus Linn. is a genus characteristic of the Old World tropics, a few species only occurring in subtropical and even in subtemperate regions. The generic range is tropical Africa and Madagascar to Japan, southward through Malaysia to eastern Australia, New Caledonia and New Zealand, eastward to Hawaii. Speciation within the limits of the Malay Archipelago (including the Philippines and Papuasia) is remarkable. As in all large genera in this vast region that are characteristic of the primary forests, there are a few widely distributed and more or less variable species, but everywhere, particularly in the insular areas, there is a very highly developed local endemism ; and a high percentage of these local endemics are very sharply defined species.

Up to 1900 about 220 binomials had been published under *Elaeocarpus*, yet Bentham and Hooker f., in 1862, most conservatively estimated the number of distinct species as about 50 ; and 28 years later K. Schumann surmised that the number might be more than 60. In the past 50 years about 330 new *Elaeocarpus* binomials have been published, mostly for optimistically proposed " new species." Anyone now attempting to work in this particular group is faced with approximately 550 published binomials under *Elaeocarpus* alone.

It was clear that in the proposals made in the past 50 years there was a considerable amount of duplication of work, due to one cause or another, but chiefly, it is suspected, because a systematist working in one place, be it Buitenzorg, Singapore, Manila, London, Berlin, or any other taxonomic center, did not have access to authentically named specimens representing many of the proposed species. The accepted priority and homonym rules are also involved. There is evidence that sometimes ample validly published descriptions were not critically studied, and in at least one case, that it was not even scanned. The situation is further complicated because too many of the proposed and described " new species " were based on fruiting specimens, or on those where only juvenile flower buds were present. Added to the confusion is the unsatisfactory work of Knuth*, who between the years 1938 and 1941, described no less than 80 new species without in any case indicating the subgenus or section, and rarely suggesting specific alliances ; twenty-two of these eighty species are herein reduced to synonymy on the basis of an actual study of excellent isotype material in each case. The Knuth holotypes were all destroyed in the Berlin disaster in 1943.

Fortunately, during the summer of 1949, I was able to examine most of the actual types of species described by Blume and by Miquel in the Leiden and Utrecht herbaria, and those of the British botanists preserved at Kew. I have, hence, in practically every case, been able to reach my conclusions on the basis of an actual examination of the types, isotypes,

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* **Knuth, R.** Elaeocarpaceae novae. Decades 1-2, Repert. Sp. Nov. **44** : 124-132 (1938) ; Decades 3-4, op. cit. **48** : 72-79 (1940) ; Decades 5-6, op. cit. **49** : 66-73 (1940) ; Decades 7-8, op. cit. **50** : 81-88 (1941).

and other historical specimens. All of the original, and many of the repeated descriptions have been studied. In difficult groups which need a thorough and critical revision on the basis of very ample collections, such as the *Elaeocarpus sphaericus* (Gaertn.) K. Schum. and *E. stipularis* Blume complexes, some future monographers may not agree with all of my proposed reductions. I am, however, confident that in the vast majority of the cases listed below, the indicated reductions will be upheld.

The net result of my studies to date is the reduction of 90 proposed binomials to synonymy; 17 of these were published before 1900, the others within the past fifty years. It is evident, as studies and comparisons are continued, that still other reductions will inevitably be made. Yet at the same time one will find in all of the large herbaria a certain number of sharply defined species which have never been studied, and which remain unnamed and undescribed. The number of these increases as collections come in from previously inadequately explored regions, and especially from those large areas which have not previously been visited by a botanist or even a botanical collector.

E. ACUMINATUS Koord. & Val. Meded. Lands Plant. **11** : 258 (1894) (Bijdr. **1** : 258), non Wall. (1830, 1874) = **E. oxypyren** Koord. & Val. op. cit. **33** : 419 (1900) ; Ic. Bogor. **3** : *pl.* 420 (1914). Java.

E. AEMULUS A. C. Sm. in Jour. Arnold Arb. **25** : 232 (1944) = **E. multiscissus** Knuth in Repert. Sp. Nov. **50** : 86 (1941). *Clemens* 5019 typifies both. New Guinea.

E. ARGYROIDES Hance in Jour. Bot. **15** : 330 (1877) = **E. griffithii** (Wight) A. Gray ; see Merrill in Jour. Arnold Arb. **19** : 50 (1938). Indo-China ; range Siam, Malay Peninsula, Sumatra, Borneo.

E. AUGUSTUS Knuth in Repert. Sp. Nov. **44** : 125 (1938) = **E. dolichobotrys** Merr. in Jour. Straits Br. Roy. As. Soc. **77** : 198 (1917). Borneo.

E. BACLAYANENSIS Elm. Leafl. Philip. Bot. **4** : 1188 (1911) = **E. sphaericus** (Gaertn.) K. Schum. fide Van Steenis in Bull. Jard. Bot. Buitenz. III, **17** : 409 (1948). Philippines ; range India to New Guinea and Samoa, i.e., *sensu lat.*

E. BARAMENSIS Knuth in Repert. Sp. Nov. **44** : 126 (1938) = **E. brevipes** Merr. in Jour. Straits Br. Roy. As. Soc. **86** : 327 (1922) ; see Airy Shaw in Kew Bull. **1949** : 165 (1949). Borneo.

E. BARBULATUS Knuth, l.c. **44** : 126 (1938) = **E. nitidus** Jack (1920) ; see Airy Shaw, l. c. Borneo ; range Malay Peninsula, Sumatra.

E. BATAANENSIS Merr. in Philip. Jour. Sci. **10** : Bot. 41 (1915) = **E. calomala** (Blanco) Merr. Philippines.

E. BELLUS Knuth in Repert. Sp. Nov. **49** : 67 (1940) = **E. merrittii** Merr. in Philip. Jour. Sci. **2** : Bot. 280 (1907). *Merrill* 5582 typifies both. Philippines.

E. BORNEENSIS Knuth, op. cit. **44** : 127 (1938) = **E. ferrugineus** (Jack) Steud. ; see Ridley in Kew Bull. **1938** : 234 (1938), and Airy Shaw, op. cit. **1949** : 165 (1949). Borneo ; range Malay Peninsula, Sumatra.

E. BECCARII Warb. in Repert. Sp. Nov. **18** : 328 (1922), non Aug. DC. (1903) = **E. euneurus** Stapf ex Ridl. in Kew Bull. **1938** : 234 (1938). Borneo.

E. BRACHYPHYLLUS Knuth, op. cit. **50** : 82 (1941) = **E. hainanensis** Oliv. in Hook. Ic. **25** : *pl.* 2462 (1896). (*E. hainanensis* Oliv. var. *brachyphyllus* Merr. in Lingnan Sci. Jour. **5** : 123 (1927). Hainan ; range Kwangtung, Indo-China, Siam, Malay Peninsula.

E. CELEBESIANUS Baker f. in Jour. Bot. **62** : Suppl. 14 (1924) = **E. teijsmannii** Koord. & Val. in Koord. Meded. Lands Plant. **19** : 368 (1898), *nom.*, Ic. Bogor. **2** : *pl.* 128 (1904), *descr.* ; see Van Steenis in Bull. Jard. Bot. Buitenz. III. **18** : 210 (1949). Celebes.

E. CLEMENSIAE Knuth in Repert. Sp. Nov. **44** : 128 (1938) = **E. clementis** Merr. in Jour. Straits Br. Roy. As. Soc. **77** : 195 (1917). The basic specimens are *Clemens* 2766, 51312. Borneo.

E. DALLASENSIS Knuth, op. cit. **49** : 69 (1940). = **E. elliptifolius** Merr. op. cit. 193 (1917). The basic specimens are *Clemens* 10783, 26231. Borneo.

E. DECORUS A. C. Sm. in Jour. Arnold Arb. **25** : 242 (1944) = **E. densiflorus** Knuth, op. cit. **50** : 82 (1941). *Clemens* 2420 typifies both. New Guinea.

E. DECURVATUS Diels in Notizbl. Bot. Gart. Berlin **11** : 214 (1931) = **E. varunna** Buch.-Ham. in Wall. List. no. 2666 (1830), *nom.*, Mast. in Hook. f. Fl. Brit. Ind. **1** : 407 (1874), *descr.* China (Kwangsi) ; range Southern China and Indo-China to Burma and Northern India.

E. DIOICUS Turcz. in Bull. Soc. Nat. Mosc. **19** (2) : 493 (1846) = **E. japonicus** Sieb. and Zucc. (1845). Japan ; range central, western and southern China.

E. ELLIPTICUS Nakai in Bot. Mag. Tokyo **18** : 67 (1904), non Sm. (1809) = **E. decipiens** Hemsl. in Jour. Linn. Soc. Bot. **23** : 95 (1886) ; see Metcalf in Sunyatsenia **6** : 178 (1941). Japan ; range Riu Kiu Islands, Formosa.

E. FAGACEUS Knuth in Repert. Sp. Nov. **44** : 128 (1938) = **E. cupreus** Merr. in Jour. Straits Br. Roy. As. Soc. **77** : 193 (1917). Borneo.

E. FERRUGINEUS Bedd. Fl. Sylv. South. Ind. *pl.* 112 (1869), non *E. ferrugineus* (Jack) Steud. (1840) = **E. recurvatus** Corner in Gard. Bull. Straits Settl. **10** : 319, 325 (1939). India.

E. FISSISTIPULUS Miq. Fl. Ind. Bat. **1** (2) : 210 (1859) = **E. stipularis** Blume Bijdr. 120 (1825), *sensu lat.* Sumatra ; range Malay Peninsula, Sumatra, Java, and Borneo.

E. FUSICARPUS Elm. Leafl. Philip. Bot. **4** : 1174 (1911) = **E. procerus** Aug. DC. in Elm. Leafl. Philip. Bot. **2** : 636 (1909) ; see Airy Shaw in Kew Bull. **1949** : 165 (1949). Philippines.

E. GAMBIR Becc. Nelle Foreste di Borneo 594 (1902), *nom.* = **E. stipularis** Blume (1825), *sensu lat.* Borneo ; range Malay Peninsula, Sumatra, Java.

E. GLABRIPETALUS Merr. in Philip. Jour. Sci. **21** : 501 (1922) = **E. sylvestris** (Lour.) Pers. Kwangtung ; range southern China, Hainan, and Indo-China.

E. GRACILIPES Knuth in Repert. Sp. Nov. **49** : 70 (1940) = **E. nitidus** Jack Mal. Misc. **1** (**5**) : 41 (1820). Borneo ; range, Malay Peninsula, Sumatra.

E. HENRYI Hance in Jour. Bot. **23** : 322 (1885) = **E. sylvestris** (Lour.) Pers. China, Kwangtung ; range, southern China and Indo-China.

E. HOLOSERICEUS Blume ex Koord. & Val. in Meded. Lands Plant. **33** : 422 (1900) (Bijdr. **5** : 422) = **E. obtusus** Blume Bijdr. **123** (1825) ; see Adelbert in Blumea **6** : 312 (1949). Java ; range Sumatra, Borneo.

E. HOSEI Merr. in Jour. Straits Br. Roy. As. Soc. **77** : 197 (1917) = **E. glaber** Blume Bijdr. 122 (1825). Borneo ; range Sumatra, Java.

E. HULLETTII King in Jour. As. Soc. Bengal **60** (2) : 132 (1891) (Mater. Fl. Malay Penin. **1** : 242) = **E. palembanicus** (Miq.) Corner in Gard. Bull. Straits Settl. **10** : 323 (1939). Malay Peninsula ; range Sumatra.

E. INTEGERRIMUS Lour. Fl. Cochinch. 338 (1790) = **Ochna integerrima** (Lour.) Merr. in Trans. Am. Philos. Soc. II. **24** (2) : 265 (1935) (*Discladium harmandii* Van Tiegh. ; *Ochna harmandii* H. Lecomte). Indo-China ; range Hainan.

E. ISOTRICHUS F.-Vill. Novis. App. Fl. Filip. 31 (1880) (*Monocera isotricha* Turcz.) = **E. calomala** (Blanco) Merr. in Philip. Jour. Sci. **10** : Bot. 43 (1915). Philippines.

E. KAJEWSKII Guillaumin in Jour. Arnold Arb. **12** : 232 (1931) = **Aceratium braithwaitei** (F. Muell.) Schltr. in Bot. Jahrb. **54** : 103 (1916) (*Aristoteleia braithwaitei* F. Muell. in South. Sci. Record **1** : 149 (1881). The type of F. Mueller's species was from Tanna, that of Guillaumin's from Aneityum, New Hebrides, and both descriptions apply to a single species.

E. KWANGTUNGENSIS Hu in Jour. Arnold Arb. **5** : 229 (1924), Contr. Biol. Lab. Sci. China **1** (2) : 3 (1925) = **E. sylvestris** (Lour.) Pers. Kwangtung ; range southern China and Indo-China.

E. LACEI Craib in Kew Bull. **1925** : 23 (1925) = **E. hainanensis** Oliv. (1896) fide Gagnepain in Lecomte Fl. Gen. Indo-Chine Suppl. **1** : 478 (1945). Siam ; range Hainan, Indo-China, Malay Peninsula.

E. LAGUNENSIS Knuth in Repert. Sp. Nov. **50** : 85 (1941) = **E. sessilis** Knuth, op. cit. 87. Philippines.

E. LEPTOPUS A. C. Sm. in Jour. Arnold Arb. **25** : 234 (1944) = **E. albiflorus** Knuth in Repert. Sp. Nov. **50** : 81 (1941). *Clemens* 1022 typifies both. New Guinea.

E. LEPTOSTACHYS Wall. List no. 2672 (1830), *nom.*, C. Muell. Anot. Fam. Elaeoc. 23 (1849), *descr.* = **E. tectorius** (Lour.) Merr. North-eastern India ; range Burma to Indo-China and the Malay Peninsula.

E. LEPTOMISCHUS Ridl. in Jour. Fed. Malay States Mus. **5** : 30 (1913) = **E. palembanicus** (Miq.) Corner in Gard. Bull. Straits Settl. **10** : 323 (1939). Malay Peninsula ; range Sumatra.

E. LEYTENSIS Merr. in Philip. Jour. Sci. **8**: Bot. 383 (1913) = **E. multiflorus** (Turcz.) F.-Vill. Novis. App. Fl. Filip. 31 (1880) (*Monocera multiflora* Turcz. in Bull. Soc. Nat. Mosc. **19** (2) : 495 (1846). Philippines.

E. LINEARIFOLIUS Knuth in Repert. Sp. Nov. **49** : 66 (1940) = **E. hainanensis** Oliv. (1896). Indo-China ; range Kwangtung, Hainan, Siam, Malay Peninsula.

E. LONGIFOLIUS Blume var. FUSIFORMIS Corner in Gard. Bull. Straits Settl. **10** : 321 (1939) = **E. submonoicus** Miq. Fl. Ind. Bat. Suppl. 407 (1862). Malay Peninsula, Borneo ; range Sumatra.

E. LONGIPETIOLATUS C. T. White in Bot. Bull. Queensl. Dept. Agr. **21** : 3 (1919), non Merr. (1917) = **E. michaelii** C. T. White in Kew Bull. **1933** : 45 (1933). Queensland.

E. LURIDUS Stapf ex Ridl. in Kew Bull. **1938** : 232 (1938) = **E. pachyophrys** Warb. in Repert. Sp. Nov. **18** : 327 (1922). Borneo.

E. MACLUREI Merr. in Lingnan Sci. Jour. **13** : 63 (1934) = **E. limitaneus** Hand.-Maz. in Sinensia **3** : 193 (1933). Hainan ; range Southern China, Indo-China.

E. MACROCARPUS Ridl. Fl. Malay Penin. **1** : 32 (1922) = *E. robustus* Roxb. (1814, 1832) fide Corner in Gard. Bull. Straits Settl. **10** : 325 (1939) = **E. tectorius** (Lour.) Merr. in Trans. Am. Philos. Soc. II. **24** (2) : 256 (1935) (**Craspedum tectorium** Lour. Fl. Cochinch. 336 (1790).) Malay Peninsula ; range north-eastern India to Indo-China and the Malay Peninsula.

E. MACROPUS Warb. ex Knuth in Repert. Sp. Nov. **48** : 76 (1940) = **E. petiolatus** (Jack) Wall. Celebes ; range Indo-China and Siam to the Malay Peninsula, Sumatra and Borneo.

E. MAGNIFOLIUS Knuth in Repert. Sp. Nov. **44** : 129 (1938), non Christoph. (1935) = **E. gustaviifolius** Knuth, op. cit. **50** : 84 (1941), *Clemens* 29481, in flower, 28078, in fruit. Borneo.

E. MAKINOI Kaneh. & Hatus. in Rept. Forest. Exp. Sta. Kyushu Univ. **3** : 119 (1933), Formosan Trees, ed. 2, 433 (1936), in syn. =*E. ellipticus* Nakai = **E. japonicus** Sieb. & Zucc. Formosa ; range central and southern China, Indo-China.

E. MAQUILINGENSIS Elm. Leafl. Philip. Bot. **8** : 3080 (1919) = **E. pendulus** Merr. in Govt. Lab. Publ. **29** : 27 (1905). Philippines.

E. MATANGENSIS Knuth in Repert. Sp. Nov. **44** : 130 (1938) = **E. pedunculatus** Wall. List no. 2678 (1830), *nom.* ; Mast. in Hook. f. Fl. Brit. Ind. **1** : 408 (1874), *descr.* Borneo ; range Malay Peninsula, Sumatra.

E. MEGACARPUS Elm. Leafl. Philip. Bot. **7** : 2627 (1915) = **E. monocera** Cav. Ic. **6** : *pl.* 501 (1801). Philippines.

E. MEGACARPUS Schltr. in Bot. Jahrb. **54** : 131 (1916), non Elm. (1915) = **E. schlechterianus** A. C. Sm. in Jour. Arnold Arb. **25** : 256 (1944). New Guinea.

E. MERRILLII Elm. ex Merr. Enum. Philip. Fl. Pl. **3** : 14 (1923), *nom.* in syn., Leafl. Philip. Bot. **10** : 3729 (1939), *descr. anglice* = **E. argenteus** Merr. in Govt. Lab. Publ. **29** : 26 (1905). Philippines.

E. MICRANTHUS Vieill. in Bull. Soc. Linn. Normandie **9** : 392 (1865) = **E. rotundifolius** Brongn. & Gris in Bull. Soc. Bot. France **8** : 261 (1861), fide Guillaumin in Not. Syst. **2** : 92 (1911). New Caledonia.

E. MICROPHYLLUS Warb. in Repert. Sp. Nov. **18** : 328 (1922), non Elm. (1911) = **E. octantherus** Aug. DC. in Bull. Herb. Boiss. II. **3** : 367 (1903). Borneo.

E. MIQUELII Hochr. Pl. Bogor. Exsic. 27 (1904), excl. spec. cit. = **E. obtusus** Blume Bijdr. 123 (1925). Java ; range Malay Peninsula, Sumatra, Borneo. (No. 50 Hochreutiner, Pl. Bogor. Exsic., is actually *E. pedunculatus* Wall., not at all the species that Miquel described and which Hochreutiner renamed.)

E. MOLLOIDES Knuth in Repert. Sp. Nov. **49** : 71 (1940) = **E. canipes** Knuth, op. cit. **44** : 127 (1938). *Clemens* 20039, 32147, one in flower, one in fruit. Borneo.

E. MYRTILLUS Schltr. in Bot. Jahrb. **39** : 180 (1906) = **E. vaccinioides** F. Muell. ex Brongn. in Bull. Soc. Bot. France **12** : 301 (1865). See Guillaumin in Not. Syst. **2** : 94 (1911). New Caledonia.

E. NIGROPUNCTATUS Merr. in Jour. Straits Branch Roy. As. Soc. **77** : 196 (1917) = **E. nitidus** Jack (1820) ; see Airy Shaw in Kew Bull. **1949** : 165 (1949). Borneo ; range Sumatra, Malay Peninsula.

E. NUTANS Knuth, op. cit. **44** : 131 (1938) = *E. tomentosus* Blume Bijdr. 121 (1825) = **E. stipularis** Blume, l. c., *sensu lat.* Borneo ; range Malay Peninsula, Sumatra, Java.

E. OCHRACEUS Ridl. in Trans. Linn. Soc. II. Bot. **9** : 21 (1916) = **Aceratium ochraceum** Schltr. in Bot. Jahrb. **55** : 194 (1918). New Guinea.

E. OCHRACEUS Stapf ex Ridl. in Kew Bull. **1938** : 230 (1938), non Ridl. (1916) = **E. cupreus** Merr. in Jour. Straits Branch Roy. As. Soc. **77** : 193 (1917). Borneo.

E. OMEIENSIS Rehd. & Wils. in Sargent Pl. Wils. **2** : 260 (1915) = **E. sylvestris** (Lour.) Pers. Szechuan ; range central and southern China and Indo-China.

E. OVALIFOLIUS Wall. List no. 2665b (1830), *nom.*, C. Muell. Anot. Fam. Elaeoc. 21 (1849), *descr.* = **E. tectorius** (Lour.) Merr. India ; range Burma to Indo-China and the Malay Peninsula.

E. OXYADENIUS Warb. in Repert. Sp. Nov. **18** : 327 (1922) = **E. beccarii** Aug. DC. in Bull. Herb. Boiss. II. **3** : 367 (1903). *Beccarii* 540 typifies both. Borneo.

E. PAPUANUS Knuth in Repert. Sp. Nov. **50** : 86 (1941) = **E. brassii** Knuth, op. cit. **48** : 73 (1940) ; see A. C. Smith in Jour. Arnold Arb. **25** : 240 (1944). New Guinea (*Brass* 7450, 7566).

E. PATENS Knuth, op. cit. **48** : 77 (1940) = **E. viscosus** Warb. in Bot. Jahrb. **18** : 201 (1893) ; see A. C. Sm. in Jour. Arnold Arb. **25** : 246 (1944). New Guinea.

E. PHILIPPINENSIS Warb. in Perk. Frag. Fl. Philip. 100 (1904) = **E. calomala** (Blanco) Merr. ; see Merr. Enum. **3** : 15 (1923) for synonymy. Philippines.

E. POLYCARPUS Stapf ex Ridl. in Kew Bull. **1938** : 230 (1938) (Aug. 15) = **E. multinervosus** Knuth in Repert. Sp. Nov. **44** : 130 (1938) (June 30). *Beccari* 2698 typifies both. Borneo.

E. POLYCHISTUS Schltr. in Bot. Jahrb. **40** : Beibl. **92** : 28 (1908) = **E. persicifolius** Brongn. & Gris in Bull. Soc. Bot. France **8** : 202 (1861). New Caledonia.

E. QUERCIFOLIUS Gagnep. in Not. Syst. **1** : 124 (1910), non Baker (1883) = **E. viguieri** Gagnep., op. cit. **3** : 133 (1915). Indo-China.

E. RAMOSII Knuth in Repert. Sp. Nov. **44** : 131 (1938) = **E. floribundus** Blume Bijdr. 120 (1925). Borneo (*Ramos* 1227) ; range British India to Indo-China southward to Sumatra, Java, and Borneo.

E. REJANGENSIS Knuth, l.c. = **E. brevipes** Merr. (1922) ; see Airy Shaw in Kew Bull. **1949** : 165 (1949). Borneo.

E. RETICULATUS Ridl. in Jour. Straits Br. Roy. As. Soc. **61** : 2 (1912), non Sm. (1809) = **E. nanus** Corner in Gard. Bull. Straits Settl. **10** : 322 (1939). Malay Peninsula.

E. RIVULARIS Vieill. ex Britten in Forbes, Nat. Wand. East. Archipel. 501 (1885), *nom.* ; Guillaumin in Not. Syst. **2** : 92 (1911), *nom.* ; Baker f. in Jour. Bot. **62** : Suppl. 14 (1924), *nom.* in nota, non Gagnep. (1910) = **E. rotundifolius** Brongn. & Gris in Bull. Soc. Bot. France **8** : 201 (1861). New Caledonia.

E. ROBUSTUS Roxb. Hort. Beng. 42 (1814), *nom.*, G. Don Gen. Syst. **1** : 559 (1831), *descr.*, Roxb. Fl. Ind. ed. 2, **2** : 597 (1832), *descr.* = **E. tectorius** (Lour.) Merr. in Trans. Am. Philos. Soc. II. **24** (2) : 256 (1935) (*Dicera craspedum* J. F. Gmel. ex DC. Prodr. **1** : 520 (1824) ; *Craspedum tectorium* Lour. Fl. Cochinch. 336 (1790)). India ; range Burma, Siam, Indo-China, the Malay Peninsula and Sumatra. See, however, Corner in Gard. Bull. Straits Settl. **10** : 325 (1939) for a rather strange dissenting opinion, considering that Loureiro's type is still extant and has been examined.

E. RUMPHII Merr. Interpret. Herb. Amb. 347 (1917) = **E. crenatus** (Raf.) Merr. Jour. Arnold Arb. **29** : 212 (1948) (*Ayparia crenata* Raf. Sylva Tellur. 154 (1838)). Amboina. An *E. sphaericus* (Gaertn.) K. Schum., *sensu lat.* ?

E. SADIKANENSIS Knuth in Repert. Sp. Nov. **49** : 71 (1940) = **E. petiolatus** (Jack) Wall. Borneo ; range Sumatra, Malay Peninsula, Indo-China, Hainan.

E. SCORTECHINII King in Jour. As. Soc. Bengal **60** (2) : 132 (1891) (Mater. Fl. Malay Penin. **1** : 233) = **E. stipularis** Blume, *sensu lat.* Malay Peninsula ; range Sumatra, Borneo, Java.

E. SERICEUS Stapf in Trans. Linn. Soc. II. Bot. **4** : 137 (1894), non Baker (1883) = **E. congestifolius** Knuth in Repert. Sp. Nov. **49** : 68 (1940). The two species were independently published. Borneo (Mount Kinabalu).

E. STENOPHYLLUS Merr. in Pap. Michigan Acad. **19** : 168 (1934) = **E. salicifolius** King in Jour. As Soc. Bengal **60** (2) : 125 (1891) (Mater. Fl. Malay Penin. **1** : 234). Sumatra ; range Malay Peninsula.

E. SUBDENTICULATUS Miq. Fl. Ind. Bat. Suppl. 408 (1862) = **E. petiolatus** (Jack) Wall. Sumatra ; range Malay Peninsula, Indo-China, Hainan, Borneo.

E. SUBGLOBOSUS Merr. in Philip. Jour. Sci. **4** : Bot. 290 (1909) = **E. sphaericus** (Gaertn.) K. Schum., fide Corner in Gard. Bull. Straits Settl. **10** : 326 (1939), et Van Steenis in Bull. Jard. Bot. Buitenzorg III. **17** : 409 (1948). Philippines ; range (*sensu lat.*) India to Southern China through Malaysia to Samoa.

E. SUBSESSILIS Hand.-Maz. in Symb. Sin. **7** : 614, *pl.* 21, *fig.* 5 (1933) = **E. sylvestris** (Lour.) Pers. Hunan, Fukien, Chekiang ; range western and southern China and Indo-China.

E. VALETONII Hochr. Pl. Bogor. Exsicc. 29 (1904) = **E. subpuberus** Miq. Fl. Ind. Bat. Suppl. 406 (1862). Sumatra ; range Bangka, Billiton, cultivated at Buitenzorg, Java (VI. C. 97) from which apparently came no. 55 of the Hochreutiner exsiccatae.

E. VERSICOLOR Elm. Leafl. Philip. Bot. **4** : 1178 (1911) = **E. cumingii** Turcz. in Bull. Soc. Nat. Mosc. **19** (2) : 491 (1846). Philippines.

E. YENGTANGENSIS Hu in Jour. Arnold Arb. **5** : 229 (1924) = **E. japonicus** Sieb. & Zucc. (1845). China (Chekiang) ; range Japan to southern and western China.

E. YENTANENSIS Hu in Contr. Biol. Lab. Sci. Soc. China **1** (2) : 4 (1925) = praec.

E. YUNNANENSIS Brandis ex Tutcher in Rept. Bot. For. Dept. Hongkong **1914** : 229 (1915), *nom.*, reprint, Chun in Sunyatsenia **1** : 170 (1933) = **E. japonicus** Sieb. & Zucc. (1845). Kwangtung, Yunnan ; range Japan to western and southern China.

VEGETATIVE HABIT IN THE GENUS EULOPHIA (Orchidaceae).

By R. E. Holttum (University of Malaya, Singapore).

(*Issued separately, 15th August, 1952.*)

SUMMARY.

The vegetative habit of the genus *Eulophia* is described, with particular reference to *E. bicarinata*.

The genus *Eulophia* (including *Lissochilus*) comprises some 300 species distributed throughout the warmer parts of the Old World, mainly in Africa. My acquaintance with it is limited to the six species occurring in the Malay Peninsula, of which five are widely distributed, two with a range from India to Australia. One of these species, which thus connects Malaya and Queensland, has only recently been found for the first time in Malaya ; it is *E. bicarinata* (also known as *E. venosa*). In vegetative form it is different from the others, and appears to be of considerable interest. It has also a connection with the late Mr. C. T. White, and the last letter he wrote me was about a drawing of this *Eulophia* which he made many years ago.

In the various descriptions of the African species of *Eulophia* which have been brought into cultivation, there is little definite information about the way in which the rhizome and pseudobulbs develop. The best source of information about vegetative structure is Pantling's beautiful plates of Sikkim orchids (King and Pantling, 1898). These drawings show the great variety of vegetative habit in the Sikkim species. Some indication of development is given, though this is not discussed in the text. These plates include the best illustration of *E. bicarinata* that I have seen.

The origin of my interest in this matter was the receipt of an inflorescence of a *Eulophia* I had not previously known. It was sent by Mr. H. J. Vallender who found plants growing near Batang Malaka in Negri Sembilan. He reported that he had seen the leaves, that they were plicate like those of *Spathoglottis* but much narrower, and that the leaves died before the flowers appeared. I found that the flowers agreed with descriptions cited by J. J. Smith under *E. bicarinata* in his enumeration of Sumatran orchids.

Wishing to prepare a description of *E. bicarinata* for my manuscript on orchids of the Malay Peninsula, I looked up the descriptions cited by J. J. Smith (they did not include Pantling's drawing) to discover details of stem and leaf, but found no such information. The original description of *E. venosa* (one of the synonyms, based on a Queensland specimen) called the plant a leafless herb. It was this that led me to write for further information from Australian botanists. I had seen the rather " sketchy " line-drawing of *E. venosa* in Bailey's Catalogue. This showed no leaf but it showed a curious prostrate tuber-like rhizome very different from any other *Eulophia* I knew. I did not realize that this was an early drawing by C. T. White, and I questioned its accuracy. Mr. White replied that he believed it was accurate, but that he had not seen a living plant of the species for many years.

Soon afterwards, Mr. Vallender sent two pieces of resting rhizome which were clearly of the same nature as that shown in White's drawing. They were whitish, tapered to both ends, and bore ring-shaped bases of decayed scale-leaves. It appeared that they grew horizontally, and they were slightly flattened. The remains of former inflorescences were not clearly distinguishable.

The two pieces of rhizome were planted in pots, and after some weeks each produced a slender erect shoot which at first consisted only of purplish sheaths. Later, foliage-leaves appeared from within the sheaths, and their development is not yet completed. The first leaf on the larger plant grew to a length of 35 cm. above the protecting sheaths, with a maximum width of 15 mm. The second leaf grew much longer though no wider, and had a distinct stalk. Both leaves were so weak that they drooped and later became folded across the middle.

At this stage I removed the larger plant from the pot and washed it carefully. The leafy shoot had arisen from a bud in the axil of one of the scale-leaves on the old rhizome ; the shoot grew straight upwards and had only a slightly swollen base which bore a few roots. The old rhizome was slightly shrunken. Directly beneath the erect leaf-shoot, and growing *downwards*, was a new fleshy organ, more or less ovoid, with a broadly rounded apex ; its surface was covered with colourless scale-leaves.

The habit thus appears to be a sympodium consisting of alternate very unequal elements, contrasting with the sympodium of equal elements in the other species of *Eulophia* in Malaya. In *E. graminea*, for example, there is a succession of equal ovoid pseudobulbs, each arising from the base of the previous one, each bearing a few narrow leaves on its upper part, and each later bearing a few inflorescences from its lower part after the leaves have withered. In *E. bicarinata* there appears to be first a short erect non-pseudobulbous leaf-bearing stem with adventitious roots at its base, and then a tuberous rhizome (covered with scale-leaves) which rests after the foliage-leaves have gone and can later bear a new leaf-shoot. I have not been able to investigate the origin of the tuberous organ ; presumably it arises in the axil of one of the basal sheaths of the leaf-bearing shoot. It seems that the tuberous rhizome begins growth downwards and continues horizontally ; whether it ends in an inflorescence-bearing part is not clear. There is the further possibility that the rhizome can bear foliage leaves near its apex, that it normally does so after resting, and that in the specimen seen by me a lateral bud developed because the terminal leaf-bearing part had been injured. Until I have had a plant under observation for some time longer, I cannot give a final answer to these questions. I write this note however in the hope that some other observers may be able to study a living plant in its natural habitat and report on its way of life.

Looking over taxonomic descriptions of many tropical monocotyledons of various families, I am impressed by the very cursory references to the subterranean parts. The variety of vegetative habit is one of the most astonishing features of monocotyledons. It is no doubt connected with their lack of a cambium, which prevents their assuming the tree-form and necessitates the development of adventitious roots. The shape of the successive parts of the stem, and their relation to one another in monocotyledons which have sympodial growth, and especially in those which form resting or storage organs, is extremely varied. A most remarkable series of examples are found within the genus *Dioscorea* as described in various works by Burkill. These examples show a great plasticity in vegetative form, the ability to change readily in adaptation to new conditions of growth owing to climatic or other habitat differences. We see this plasticity also in the genus *Eulophia*, though on a much smaller scale than in *Dioscorea.*

There are doubtless many similar curious facts hidden under such statements as "rootstock tuberous," or "roots fibrous" in our older taxonomic works, and the student of tropical plants may find much of interest in the investigation of plants so described.

The wide geographic distribution of most of the Indo-Malaysian species of *Eulophia* is no doubt to be explained by the fact that they are plants of open places, not of moist shady forest. The fact too that they are mostly seasonal in growth and flowering makes them unsuited to the very uniform climate of Malaya in which dry seasons are neither long enough nor regular enough to induce regular periods of rest. Many such widely distributed species of seasonal habit do not occur in southern Malaya though it falls within their geographic range.

I conclude with a statement of the synonymy of *Eulophia bicarinata*, as given by J. J. Smith, with the additional references to illustrations.

Eulophia bicarinata (Lindl.) Hook. fil. Fl. Brit. Ind. **6** : 6 (1890) ; King & Pantl. in Ann. R. Bot. Gard. Calc. **8** : 180, t. 244 (1898).

Cyrtopera bicarinata Lindl. Gen. et Sp. Orch. 190 (1833).

Eulophia venosa Rchb. fil. in Benth. Fl. Austr. **6** : 300 (1873) ; Bailey Compreh. Cat. Queensl. Pl. 529, fig. 515 bis (1913).

Cyrtopera papuana Kranzl. in Notizbl. Bot. Gart. Berlin **2** : 104 (1898).

Eulophia venosa var. *papuana* Schltr. Orch. D. N. Guin. 416 tab. 145, no. 545 (1912).

E. versteegii J.J.S. in Bull. Dep. Ag. Ind. Néerl. **19** : 24 (1908) ; Nova Guinea **8** : 25, t. **9**, 5 (1908).

E. neo-pommeranica J.J.S. in Nova Guinea l.c., 26.

Cyrtopodium parkinsonii F. Muell. et Kranzl. in Oesterr. Bot. Zeitschr. **44** : 256 (1894).

RHEOPHYTES.

By C. G. G. J. van Steenis, Rijksherbarium, Leiden, Holland.

(With Plates II. and III.)

(Issued separately, 15th August, 1952.)

SUMMARY.

Rheophytes are plants confined to stream-beds and, though they belong to widely different families, they have certain morphological characters in common. A preliminary list of those occurring in Australia is given, together with an amended account of the genus *Torrenticola*.

Rheophytes are, by definition (van Steenis 1932), plants distributionally confined to stream-beds, below flood level. They occur especially in swift running water of streams subject to overflowing.

Plants of very different structure and systematic status belong to this class of plants which has hitherto been little recognised as a separate ecological group. This is rather strange because streams are generally, in the tropics, the natural highways of the forest.

To those who are acquainted with some typical rheophytes, it is clear that they deserve to be classed together. Rheophytes occupy a special ecological niche in nature. As I observed several rheophytes in Australian waters, I want to focus the attention of Australian botanists on this specialized group, with which I first became acquainted in my boyhood at Utrecht, Holland. In a swift-running stream near this town, the identity of a gregariously occurring, submerged, ribbon-leaved water-plant which never flowered puzzled me for a long time. In passing, it appeared to represent a rheophytous variety of *Sagittaria sagittifolia* known exclusively from streams and rivers.

Since that time I have paid special attention to plants restricted to stream-beds and have found some similarity in their behaviour. I have also gradually accumulated a large number of remarks and notes in literature from all parts of the world and extracted data from floras, plant lists, and expedition reports. In all, I have notes on several hundred rheophytes, and it appears that they occur all over the world both in wet and semi-arid countries.

H. N. Ridley (1893) in a report on the flora of the east coast of the Malay Peninsula wrote :

> " The hills which enclose the rocks are upward of 2,000 feet in altitude, and are composed of quartzite, clad to the top with tall trees. One could not but be struck with the similarity in form of the foliage of the chief plants which grew close to the water's edge. There was here quite a series of plants with peculiarly long, narrow, acuminate leaves, such as the specific name *salicifolia* suggests. They belonged to all manner of orders and included a *Calophyllum*, an *Ixora* (I. *stenophylla* Miq.), a *Hygrophila* (*H. saxatilis* n.sp.), an *Antidesma* (*A. salicifolia* Miq.), a *Didymocarpus* (*D. salicina* n.sp.), a new genus of the Asclepiadaceae (*Spiladocorys*), a *Podochilus* (*P. maingayi* Hook. f.), a *Ficus* (*F. pyriformis* Hook.), a *Rhynchopyle*, and a *Melastoma*.
>
> The forms of leaves in the tropical woods bear a great relation to the amount and force of the rainfall. During a tropical shower it is easy to see how well the commonest form of jungle leaf (a lanceolate, acuminate or caudate one) is adapted for throwing off the heavy rain rapidly. But the form of the narrow leaf among the plants mentioned above seemed to me to be the result of adaptation to avoid another danger.

> All these plants grow on rocks near the water's edge, and as the river is subject to very rapid rises from sudden falls in the mountain districts, these plants are liable to submersion in a violent rush of water. Broad foliage would be torn off or mutilated, but narrower leaves, offering a less resistance to the water, would receive no injury. One may compare with this the narrow floating leaves of the aquatic *Ranunculi* and Potamogetons which inhabit the rapid streams in Europe.
>
> The islands of the Tahan river formed of boulders produced several interesting plants, including *Homonoia*, not hitherto recorded south of Siam, a curious new and shrubby *Phyllanthus*, and abundance of the beautiful *Arundina speciosa* Bl."

This excellent description was preceded by observations of the great Italian explorer O. Beccari whose report, however, appeared later and is hidden in the pages of that most interesting book " Nelle foreste di Borneo " with the English translation " Wanderings in the great forests of Borneo " (1904). On page 392 of the latter he wrote :—

> " *Stenophyllous plants.* I have adopted this term for certain plants growing on river banks or in the beds of torrents, which have linear or else very narrow leaves—narrower than those of congeneric species growing in the forest. By this I do not mean that every plant with narrow leaves must of necessity grow by the side of rivers nor that it is only in Borneoan rivers that such are observable. That plants with linear leaves have such a habitat is well known, and I need only mention as an example the many species of *Salix* so frequent in such localities.
>
> In Borneo, however, along the inland rivers, stenophyllism appears to me much more accentuated, and more instructive by reason of the fact that the plants exhibiting this characteristic are numerous, and in many cases very strictly localized. They thus give one the idea of growing on the spot where they modified their structure, and more especially their leaves, in compliance with the stimulus received. I am inclined to ascribe the stenophyllism as due to the action of the continuous currents of air, so constant along rivers, and secondly, to that of periodical floods. In the latter case stenophyllism is associated with great flexibility and toughness of the stems and branches, such as that exhibited by several species of *Salix* (here follow many examples of plants collected by him). . . . I believe also that, although these species appear to be highly localized forms, they may be found along other rapid rivers subject to sudden inundations."

The observations of Beccari eminently supplement those of Ridley and leave no doubt about the existence of rheophytes. Many later collectors and writers have recognised them in collections, *e.g.*, Merrill, in his studies on the Philippine and Bornean flora, and Endert, Beumée, Burkill, Holttum and Corner.

Beccari rightly drew attention to the fact that it is not strange that these plants are suited to stream-bed conditions, but that the main question is : why are they, in nature, limited to the part below flood-level ?

As in similar ecological groups, such as the saprophytes, hydrophytes, myrmecophytes, cushion plants, epiphytes, ephemerals, geophytes, etc., the representatives show a number of parallel adaptive characters in common but their representatives are scattered through all orders of the vegetable kingdom. Rheophytes are known among the Cryptogams (Algae, Bryophytes, Pteridophytes), and among the lower organisms they are mostly known as torrenticolous forms. In zoology the term rheobiology has been coined for studies of organisms confined to running waters. Among the Pteridophytes, which comprise a rather large number of rheophytes, the most singular representative is the leafless *Ophioglossum inconspicuum* v.A.v.R. occurring in Papua in gravel-beds covered with *Saccharum spontaneum*. According to my numerous data, rheophytes occur in about 60 families of flowering plants. Some families contain a large number, *e.g.*, the Acanthaceae, Araceae, Moraceae (mainly *Ficus*), Myrtaceae, Euphorbiaceae, Compositae, and Rubiaceae. Most unexpected families and genera have produced rheophytous species, *e.g.*, a *Quercus* in Hainan, *Buxus* in the Philippines, and *Notelaea* in New Caledonia.

Very often rheophytes can be recognised in floras or plant lists by their specific epithet referring either to habit or leaf shape which has struck the collector or the phytographer; epithets like *salicinus*, *rheophila*, *stenophylla*, *riparia*, *lanceolata*, *viminea*, *virgata*, *linearis*, and *salicoides* have often been given to rheophytes.

Among rheophytes there is only one family of which all members are confined to rapids and torrents, viz., the highly specialised Podostemaceae. An emended description and a plate of the only Australian representative of the family are given below.

Of the other families, there are some genera, often monotypic, which consist exclusively of rheophytous species, *e.g.*, *Rhabdia* (Borraginaceae), *Nerium* (Apocynaceae), *Enaulophyton* (Melastomaceae), *Myrmeconauclea* (Rubiaceae), *Pentasacme*, and *Dorystephania* (Asclepiadaceae).

Most frequently, however, a genus includes only one or a few rheophytous species, but more than one occur in *Neonauclea* (Rubiaceae), *Antidesma* (Euphorbiaceae), *Ficus* (Moraceae), *Syzygium* (*Eugenia*) (Myrtaceae), *Aglaia* (Meliaceae), etc. Rheophytes may also be represented by a subspecies or a mere variety of some non-rheophytous species. Among Gramineae, Cyperaceae and Liliaceae, several species belong to the rheophytes; their representatives are naturally stenophyllous.

Also among water-plants (hydrophytes) some species are typical rheophytes. In a certain sense all rheophytes are hydrophytes, but it should be realized that practically all are perennial, and that the majority are woody, suffruticose or shrubby, 1-2 m. tall, or even small to medium-sized trees. Some of the latter are, hence, only typical rheophytes (subject to the current) in their juvenile stage; in their later stage their crown is elevated above the stream and no longer affected by floods. Anyhow, the woody rheophytes have been derived from land-plants, behave as such, and at least find their closest relatives among land-plants. Moreover, most hydrophytes possess hygrophytic leaves, but the foliage of rheophytes is definitely not hygrophytic, but rather tough and firm, subcoriaceous to coriaceous in the herbarium. None of them has membranaceous leaves. Doubtless their leaves are provided with fibres or other sclerenchyma. Probably rheophytes are more heliophilous than hygrophilous. Hardly any rheophyte possesses hairy leaves, and hardly any has toothed leaves; if present, marginal teeth and incisions tend to be of the crenate type. When cultivated, the structure of the leaves proves to be absolutely constant, as I have observed in *Nerium*, *Homonoia*, *Eupatorium riparium* and others.

The stems of the rheophytous trees are sometimes distinctly streamlined in section, possibly owing to tensions in the stem and the symmetrical root-system which is elongated in both ways in the direction of the stream. Also, the crown is oblique, the water-current having a similar distorting effect as constant winds can have on trees and shrubs (wind-forms).

The equipment of the rheophytes shows three specializations in connection with the habitat, namely :—

(*a*) Strong and wide root-system able to anchor in moving gravel and boulders, or very thick root-matting to adhere to the rocks.

(*b*) Tough, flexible structure of stems because of abundance of fibres in order to give resistance to the swift current in the struggle for self-preservation and maintenance.

(*c*) Peculiarities of fruit and seed, season of fruiting and seeding, germination of seeds, and dispersal methods of seeds. Seeds of *Podostemaceae* are able to stick to surfaces. In many other rheophytes seeds or fruits are able to drift.

In habit, many shrubby rheophytes have some typical field-characters in common.

(*d*) Stream-lined leaves, very often more or less falcate and attenuate, with high leaf-index, *i.e.*, length divided by width, exceptionally 2 (in *Myrmeconauclea*), mostly much more than 3 ; that is, they are at least lanceolate.

(*e*) Broomlike, umbrella-shaped or table-shaped habit of the crown, caused mostly by sympodial, often virgate branching in such a way that the foliage comes more or less in one plane. The crown is often oblique and elongated in the direction of the stream.

(*f*) Reductions frequently occur in genera with compound leaves, *e.g.*, in the Pteridophytes and Meliaceae, where the leaves of the rheophytic members of a genus are reduced by comparison with allied species, sometimes simple.

Once one has recognised rheophytes, these plants can be picked out of a collection at sight (with the exception of Monocotyledons) and field notes on the label generally confirm one's impression, as I have found on many occasions. Next to the *Salix*-like leaves, they have something peculiar in their habit difficult to define in words. To call them " virgate " is too strong : specimens have often mud or drift between the foliage left after flooding, and sometimes they have been slightly damaged by the flood waters.

A noteworthy experience is that rheophyte communities hardly ever consist of one species : mostly several are found together in colonies where the current, and hence the " soil," is suitable. Rivers and streams are the gutters of Nature where, among the debris, diaspores of plants belonging to the most different ecological niches accumulate.

To find out whether a plant can be defined as an obligatory rheophyte, expert field-knowledge is always needed, and sometimes it can not be judged locally. One has to look up as many specimens in herbaria as possible, and check literature. Unfortunately most handlists and floras seldom define the ecological habitat of the species. Also, collectors often forget to make a concise note on the habitat of their specimens for the herbarium. In checking whether a species found in a river-bed below flood level is a rheophyte, one ought to make a study of its geographical distribution. Most plants from river-beds are occasionals ; they are often able to germinate and grow in the river-bed, but their station is mostly temporary, and depends on regular and fresh supplies of diaspores by which their stations may appear continuous. Sometimes hydrophytes, saxophytes or hygrophytes may be able to find a sheltered place on rocks or under rocks where they can survive locally because they are not exposed to the direct force of the stream. These facultative rheophytes representing the bulk of the stream-bed flora, can easily be distinguished on the strength of their occurrence elsewhere outside the rheophytic habitat.

In Australia, some difficulties are encountered, because many water-courses have, specially in dry regions, accumulations of a varied flora ; also the height of the floods is very variable, and many streams are typical "wadis," that is, they are flooded at long intervals. Here, one ought to be careful not to confuse riverine species—that is, those which occur along streams or in well-watered ravine-beds—with true rheophytes.

If one wants to look for rheophytes, attention should be focussed, not on sluggish, silted stream-beds, but on streams containing clear water with a bottom consisting of coarse sand, pebbles, boulders or rocks and streams with cascades and rapids. An examination should be made of gravel, bars, and crevices of rocks and ledges.

During my rather hurried visit to East Australia (July-August 1950) I got the impression that Australia harbours many rheophytes, some of which I observed through the kind help received from all colleagues whom I met, and many hints from memory or literature were given.

My Australian records have not been properly checked with herbarium collections or with the literature, some of which is not available to me. Therefore, this provisional list is more an invitation to criticism and a request for additional information than anything else. I will be extremely grateful for help in tracing true rheophytes. Some time I intend to arrange my growing number of notes into book form.

Casuarinaceae :

Casuarina cunninghamiana Miq. ! River oak. Seen near Canberra.

Compositae :

Olearia argyrophylla F. Muell.

Cyperaceae :

Carex alsophila F. Muell.

Carex gaudichaudiana Kth.

Carex polyantha F. Muell.

Leguminosae :

Acacia salicina Lindl.

A. stenophylla A. Cunn.

Liliaceae :

Lomandra longifolia Labill. vel. aff. An apparently distinct rheophytic variety or subspecies or an allied species was seen near Brisbane.

Malvaceae :

Plagianthus pulchellus A Gray.

Myrtaceae :

Callistemon salignus Sweet.

C. subulatus Cheel.

C. viminalis (Sol.) Cheel. Red bottle-brush. Seen near Brisbane and Canberra.

Eucalyptus camaldulensis Dehnh.

E. coolabah Blakely & Jacobs.

E. largiflorens F. Muell. (syn. *E. bicolor* A. Cunn.) should be a rheophyte in the river Murray and tributaries.

Eugenia (*Syzygium*) *eucalyptoides* F. Muell.

E. smithii Poir.

E. tierneyana F. Muell.

E. ventenatii Benth. Weeping myrtle. Seen near Brisbane.

Melaleuca bracteata F. Muell. River tea-tree.

M. leucadendron L. var. *mimosoides*, var. *saligna*, and var. *argentea* according to Mr. White. Weeping tea-tree.

Tristania laurina R.Br. Water gum. Seen near Brisbane.

T. neriifolia R.Br. Water gum.

Podostemaceae:

Torrenticola queenslandica Domin.

Polypodiaceae:

Lomaria discolor Mett.	(probably hygrophyte ?)
L. lanceolata Sturm.	do. ?
L. fluviatilis Mett.	do. ?

Proteaceae:

Lomatia myricoides Gaertn. ! (syn. *L. longifolia* R.Br.). Apparently one form only. Seen near Canberra and Sydney.

Thymelaeaceae:

Pimelea axiflora F. Muell.

Violaceae:

Hymenanthera angustifolia R.Br. (syn. *H. dentata* R.Br.).

A note should be added about the use made of some rheophytes, for with the exception of the Podostemaceae, a number of them can be cultivated outside streams. Ornamentals are *Gardenia jasminoides* Ellis and *Nerium oleander* L. For *Nerium*, I checked the habitat of all wild specimens in the Mediterranean and Near East in the Kew Herbarium, and it proved to be a true rheophyte. The gregarious growth and ability to form extensive root systems have induced man to use rheophytes for protection of the soil against erosion. I found *Homonoia riparia* planted in North Sumatra along and in watercourses between steep rice-fields for protecting the banks. For protecting steep road-talus along roads in tea and chinchona plantations in West Java, *Eupatorium riparium* and *E. triplinerve* are extensively used. The tough, flexible stems have induced man to use *Salix* in Europe and elsewhere for matting purposes. This finds its equivalent with the Dayak people in West Borneo who use *Ardisia linearifolia* Miq. for making traps and baskets for fishing purposes.

EMENDED DESCRIPTION OF TORRENTICOLA QUEENSLANDICA Domin.

The oldest record of a Podostemacea occurring in Queensland is the note by F. Mueller (1882) where he mentions a " genus and species not yet determined," a fact recognised by F. M. Bailey (1901) who added " that the authority rested upon specimens collected by Mr. Walter Hill at the Johnstone river in 1873. In 1874, Oliver sent specimens to E. Weddell who recognised the species as new, but could not place it." Domin studied this material and described it provisionally as representing a new monotypic genus, *Torrenticola queenslandica* with the alternative name *Podostemon torrenticolum* (Damin 1925). His description was based on fruiting material only.

In 1935 the late orchidologist C. E. Carr collected in the Laloki river cataracts, near Rona, Papua, the same species in fruit and flower. In 1947 I identified this with the Queensland plant of Domin, and later reproduced an ample figure (1949). In July 1950 I discussed this neglected plant with Mr. C. T. White with whom I had the great privilege of staying seven memorable days at Brisbane. Mr. White, who showed me unforgettable kindness and friendliness, gave me a little tube containing some sterile shoots of a tiny plant which he correctly took to be *Torrenticola queenslandica*, but most probably representing a vegetative growth different from the fertile stems. This difference of sterile and fertile shoots has been observed in many Podostemaceae. The material was collected by Mrs. M. J. Mackerras, Oct. 12, 1949, in Babinda Creek, near Cairns, NE. Queensland, growing on smooth granite boulders in fast water. This is a second locality for Queensland, and more records can be expected. Fertile material can be collected during the dry period when the level of the water is low.

The description of the species, copied from the Flora Malesiana, is as follows :—

Torrenticola.

Domin, *nom. prov.* Bibl. Bot. 89, 2 (vol. 20) (1925) 149, t. 35, f. 7-13 ; Engl. in E. & P. ed. 2, 18a (1935) 484 ; Steen. J. Arn. Arb. 28 (1947) 421 ; Fl. Mal. 4^2 (1949) 66.—Podost. indet. F. v. M. Syst. Cens. (1882) 23 ; 2nd Cens. (1889) 166 ; Bail. Compr. Cat. (1913) 417.—Podostemon sp. Domin, *l.c.*, *nom. alt.*

Roots lingulate, sparsely ramified ; sprouts very close, erect, mostly simple, rarely branched, thin, ridged, densely foliated. Leaves distichous, equitant, base laterally compressed, obtriangular, upper ones toothed, minute, thick, 1-2 carinate, decurrent, lowest semi-amplexicaulous, blade ± patent. In sterile submerged shoots the central tooth of the leaves is elongated into a filiform appendage. Flowers single, apical, strongly asymmetric. Spathella sub-oblique, tipped, irregularly circumscissile-dehiscent. Flower shortly stalked. Tepals 2, narrow, small. Stamen 1, articulate with the pedicel, in bud appressed to the ovary, filament broad, anther broad, connective emarginate, cells introrse. Pollen grains 2-celled. Ovary ± globular, smooth, 2-locular with 2 grooves where the dissepiment is attached ; stigmas 2, oblong-lanceolate, in bud appressed to the ovary towards the stamen. Fruit slightly oblique, terete, the largest valve persistent, ribs 10, indistinct. Placenta globular, surrounded by a thin narrow membranous dissepiment, caducous. Seeds numerous sub-angular oblong.

Distr. Monotypic, Queensland and Malaysia : SE. New Guinea.

Note. Vegetatively, *Torrenticola* reminds of certain S. American species of *Podostemon*, but the flowers and fruit indicate its affinity with the Malaysian *Cladopus*.

Torrenticola queenslandica Domin, l.c. ; Engler, l.c. ; Steen ll. cc.—*Podostemon* sp. Domin, l.c. nom. altern.

Roots ca $\frac{1}{2}$-2 mm. broad. Stems $2\frac{1}{2}$-$6\frac{1}{2}$ cm. long, densely set, dark-green. Leaves ridged on the back, ca $\frac{1}{2}$-2 mm. long. Filiform appendages in sterile specimens to 15 mm. long. Spathella ± sessile, to ± $\frac{1}{2}$ mm. stalked, ± 2 mm. long. Pedicel $\frac{1}{2}$-$1\frac{1}{4}$ mm. in bud, 2 mm. in fruit. Tepals ± $\frac{1}{2}$ mm. long, filament ± $\frac{1}{2}$ mm. long, thecae ± $\frac{3}{4}$ mm., cells slightly unequal, pollen grains ± 30 μ. Ovary $1\frac{1}{4}$ mm. diam. ; stigmas ± $\frac{1}{2}$ mm. ; seeds ca $\frac{1}{4}$-$\frac{1}{3}$ mm. diam.

QUEENSLAND: Johnstone River, *W. Hill*, 1874; Babinda Creek, *Mrs. M. J. Mackerras*, Oct. 12, 1949 (Herb. Brisbane).

PAPUA: Laloki River, near Rona, *C. E. Carr* 12415, 1935 (Herb. Brisbane, Canberra, Melbourne).

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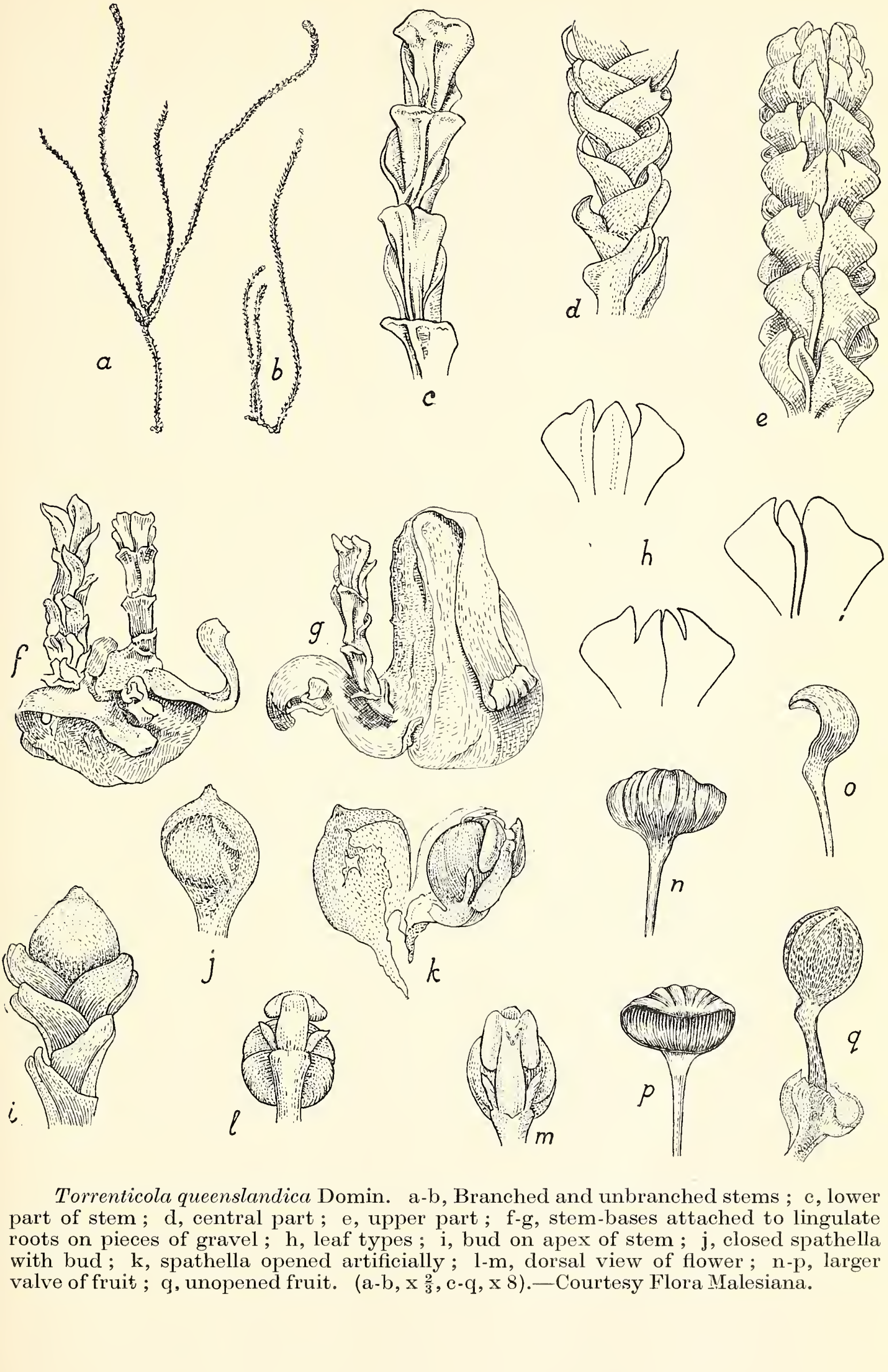

Torrenticola queenslandica Domin. a-b, Branched and unbranched stems ; c, lower part of stem ; d, central part ; e, upper part ; f-g, stem-bases attached to lingulate roots on pieces of gravel ; h, leaf types ; i, bud on apex of stem ; j, closed spathella with bud ; k, spathella opened artificially ; l-m, dorsal view of flower ; n-p, larger valve of fruit ; q, unopened fruit. (a-b, x $\frac{2}{3}$, c-q, x 8).—Courtesy Flora Malesiana.

Torrenticola queenslandica Domin. Specimen from Babinda Creek, stem x 2, separate leaf x 3.

PSEUDORAPHIS SPINESCENS (R.Br.) n. comb., AND SOME RECORDS OF NEW SOUTH WALES GRASSES.

By Joyce W. Vickery, National Herbarium of New South Wales, Botanic Gardens, Sydney.

(Issued separately, 15th August, 1952.)

SUMMARY.

A new combination in the Gramineae is proposed; six grasses are reported from New South Wales for the first time.

Pseudoraphis spinescens (R.Br.) n. comb.

Panicum spinescens R.Br. Prodr. 193 (1810).

Chamaeraphis spinescens (R.Br.) Poir. Encycl. Meth., Suppl. **2**: 189 (1811).

Chamaeraphis spinosa Beauv. ex Roem. et Schult. Mant. **2**: 253 (1824), apparently based on *Panicum spinescens* R.Br.

Panicum asperum Koen. in Naturforscher. **23**: 209 (1788); not *Panicum asperum* Lam. (1778).

Chamaeraphis aspera (Koen.) Nees in Wall. Cat. Herb. Ind. No. 8679 (1849).

Pseudoraphis aspera (Koen.) Pilger in Notizbl. Bot. Gart. Berlin **10**: 210 (1928).

Panicum abortivum R.Br. Prodr. 193 (1810). (*See* also Kunth Enum Pl. **1**: 131 (1833).

Chamaeraphis abortiva (R.Br.) Poir. Encycl. Meth. Suppl. **2**: 189 (1811).

Orthopogon abortivus (R.Br.) Spreng. Syst. Veg. **1**: 306 (1825).

Chamaeraphis spinescens var. *parvispicula* Benth. Fl. Austral. **7**: 499 (1878), based on *Panicum abortivum* R.Br.

Pseudoraphis abortiva (R.Br.) Pilger in Notizbl. Bot. Gart. Berlin **10**: 210 (1928).

In the Herbarium of the Royal Botanic Gardens, Kew, there are two sheets from Robert Brown's collections, No. 6126 named *Panicum spinescens* and No. 6127 named *P. abortivum*. Each sheet bears two specimens, and from the appearance it seems that one piece from each sheet has been transposed. There is no doubt that these sheets bear parts of the type-collections of Robert Brown's two species. On comparison I could find no significant difference between them. There is a slight difference in size of the spikelets, but I have found as great a difference in size of spikelets on the one specimen in various Australian collections. I am therefore disposed to regard them as conspecific.

The species is now referrable to the genus *Pseudoraphis* Griffith ex Pilger, and it becomes necessary to select the appropriate specific epithet available for use in this genus. Pilger referred *Panicum spinescens* to *Pseudoraphis aspera*, based on *Panicum asperum* Koen. described in 1788 from an Indian and Malayan grass. But this is a later homonym, being pre-dated by *Panicum asperum* Lam. (1778). The epithet was subsequently used in *Chamaeraphis* by Nees in 1849, and for priority considerations would rank only from that date. It is necessary therefore to select one of the earlier epithets simultaneously used by Robert Brown. Article 56 of the International Rules provides *inter alia* that " If the names or epithets are of the same date, the author who unites the groups has the right of choosing one of them. The author who first adopts one of them, definitely treating another as a synonym or referring it to a subordinate group, must be followed." Bentham (1878) appears to have been the first definitely to select the epithet " spinescens " and refer *Panicum abortivum* to a subordinate group, to *Chamaeraphis spinescens* var. *parvispicula*. Stapf (1906, p. 348) also clearly adopted " spinescens " and relegated " abortivum " to synonymy. The epithet " spinescens " must therefore be adopted also in *Pseudoraphis*.

In describing *Panicum abortivum*, Brown refers to *Andropogon squarrosus* Herb. Linn. He did not refer to *Andropogon squarrosus* Linn. f. Suppl. Pl. 433 (1781). It seems evident therefore that he was identifying a specimen in the Linnean herbarium with his *P. abortivum*, but was deliberately refraining from including *Andropogon squarrosus* Linn. f. in the synonymy. The identity of *Andropogon squarrosus* Linn. f. has puzzled generations of systematic botanists, but only those aspects of the problem which relate to *Panicum abortivum* need concern us here. Certain elements of its description strongly suggest an aquatic member of the Andropogoneae such as a *Vetiveria* sp., *e.g.* " Flos hermaphroditus sessilis, masculi pedicellati." For this reason it has been held by some to apply to *Vetiveria zizanioides* (L.) Nash (syn. : *Andropogon muricatus* Retz.), although this view was not held by Stapf (1906, p. 346). Moreover, the description of the glumes could apply to *Panicum abortivum* only on the assumption that Linnaeus failed to observe the short lower glume. There seems no doubt that there is a specimen in the Linnean herbarium which agrees with *P. abortivum*; Brown's observations on this specimen were confirmed by Stapf (1906, p. 348). However, the problem remains as to whether this specimen is in fact that from which Linnaeus drew up his description of *Andropogon squarrosus*, and therefore whether it is the type of the species. In view of the confusion which already surrounds this name, it seems undesirable to adopt it in *Pseudoraphis* until the matter has been placed beyond all doubt.

Chase (1925, p. 203) has taken a different view, and adopted the epithet " squarrosus " for *Panicum abortivum* and probably *P. spinescens*, treating Brown's reference to Herb. Linn. as indicating definite synonymy. For completeness the synonymy involved by this interpretation of the basonym is given below, but as already indicated this view is not accepted by the present writer, and these synonyms are not held to be applicable to *Pseudoraphis spinescens*.

Andropogon squarrosus L.f. Suppl. Pl. 433 (1781).

Panicum squarrosum (L.f.) Lam. Encycl. Meth. **4** : 743 (1798).

Anatherum squarrosum (L.f.) Beauv. Agrost. 128, 150 (1812).

Echinochloa squarrosa (L.f.) Roem. et Schult. Syst. Veg. **2** : 479 (1817).

Orthopogon squarrosus (L.f.) Spreng. Syst. Veg. **1** : 307 (1825).

Chamaeraphis squarrosa (L.f.) Chase in Contrib. U. S. Nat. Herb. **24** : 203 (1925).

Pseudoraphis squarrosa (L.f.) Chase in Journ. Arn. Arb. **20** : 313 (1939).

Pseudoraphis spinescens ranges from India, Ceylon, South China, Borneo, the Philippines and New Guinea to Australia. It is characteristically rooted in mud with the stems rising above shallow water in pools or rivers. It occurs in all Australian States except Tasmania. In New South Wales it is more commonly found along inland rivers and lagoons, though obtained by Robert Brown from the Port Jackson district.

Cleistochloa subjuncea C. E. Hubbard in Hook. Ic. Pl. **33** : t. 3209 (1935).

This species is known from many collections in Queensland, but only recently it was obtained in New South Wales, at Gordon Vale, south of Yelarbon, Queensland, 25–11–1949, *F. Hely* (*NSW* 13683).

Dimorphochloa rigida S. T. Blake in Univ. Queensl. Papers, Dept. Biol. **1**, No. **19** : 2 (1941).

Originally known only from a somewhat restricted area on sandstone ridges and hills in the Leichhardt, Warrego and Darling Downs districts of Queensland, Blake has informed me that he has since found it at Mt. Maroon, thus extending its range about 200 miles to the south-east. It is now recorded from two localities a little west of the Sydney district in New South Wales, some 600 miles to the south. Here, as in Queensland, it was found on sandstone ridges. N. S. Wales : Bent's Basin, Nepean River, 9—1913, *E. Cheel* and *J. L. Boorman*, (*NSW* 13688) ; on ridge above Upper Colo, 29–3–1950, *J. Vickery* (*NSW* 11006).

Sehima nervosum (Rottl.) Stapf in Prain, Fl. Trop. Afr. **9** : 36 (1917). (Syn. : *Ischaemum laxum* R.Br.).

This species extends from Tropical Africa and Tropical Asia to Tropical Australia. It was first recorded from New South Wales by F. Turner (1891, 1895), who reported a specimen from Tamworth. It was therefore accepted as a component of the New South Wales indigenous flora by C. Moore (1903, p. 85) and by Maiden and Betche (1916). Turner's collections are apparently no longer extant, and there have been no specimens of *Sehima nervosum* from this State in the New South Wales National Herbarium until recently. Turner's record has now been confirmed by a specimen received from northern New South Wales, some 20 miles north of Warialda at " Freestone," Coolatai, on a stony basalt hill, badly eroded, with very shallow soil between stones, 29–12–1950, *A. Johnson* (*NSW* 13681).

Brachypodium distachyon (L.) Beauv. Agrost. 101, 155, 156 (1812).

This small annual, a native of the Mediterranean region, has been known in the southern Australian States for many years. As might be expected, it appears to be advancing northwards into New South Wales, where its presence is definitely established by the following record : Howlong to Brocklesby Road, 30–11–1949, *E. J. McBarron* 4189 (*NSW* 13690).

Phalaris angusta Nees ex Trin. Gram. Icon. **1** : t. 78 (1827).

This native of southern America has been cultivated experimentally by the New South Wales Department of Agriculture. It now appears to have become naturalised in at least one area—Windsor district, 12–1949, *J. N. Whittet* (*NSW* 10592).

Digitaria orbata Hughes in Kew Bull. **1923** : 312 (1923).

This species was described from Herbert's Creek, Queensland. The type is in the Herbarium of the Royal Botanic Gardens, Kew, and a specimen from Cairns in the New South Wales National Herbarium is an excellent match for it. Some specimens recently collected in northern New South Wales just south of the Queensland border are referred to this species. It differs from the related *D. diminuta* Hughes, a not uncommon species in New South Wales, in the upper glume which is still further reduced to an extremely small scale, the back of the upper (fertile) lemma being almost entirely exposed.

New South Wales : Red Hill, Gordon Vale, south of Yelarbon (Queensl.), 23–11–1949, *F. Hely* (*NSW* 10732, 10733, 10734).

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THE SIGNIFICANCE OF THE MALLEE HABIT IN EUCALYPTUS.

By N. T. Burbidge, C.S.I.R.O., Canberra.

(Issued separately, 29th August, 1952.)

SUMMARY.

The mallee and probably also the marlock form in *Eucalyptus* are considered to be of recent origin; possibly developing in response to the severe change in climatic conditions which occurred at the end of the Pleistocene. Mallees and marlocks are found in a number of different sections of the genus but there is no evidence that they are either primitive or that they have been associated with a particular line of development. Though they may have had an independent origin in different parts of the continent, the chief centre of development for the species most conspicuous in the "Mallee" ecological association appears to have been in the Southern Eremaea in Western Australia. This area is regarded as a secondary centre of speciation for the genus. The migratory routes of certain birds may have been associated with the migration of these mallee species to the eastern parts of Australia.

The plant form in *Eucalyptus* falls into three main categories: (i) Trees, (ii) Mallees, in which a number of woody stems carrying scanty foliage arise from an underground woody stock, and (iii) shrubs or mallee-like plants in which the woody stock is absent or poorly developed. The mallee-like plants in the last group are commonly referred to as marlocks in Western Australia and this colloquial term will be used here.

Examples of mallee species are: *E. morrisii* (*Macrantherae-Exsertae*) from the Flinders Range to western New South Wales; *E. diversifolia* (*Renantheroideae-Diversiformae*) along the coast from Western Australia to Victoria; *E. stricta* (*Renantheroideae-Fraxinales*), central coast of New South Wales and the Blue Mountains but not a very typical mallee; *E. leptophylla* (*Porantheroideae-Fruticosae*), Western Australia to Victoria; *E. gracilis* (*Graciles-Aridae*), Western Australia to New South Wales and Victoria; *E. cneorifolia* (*Micrantherae-Eremophilae*), Kangaroo Island, South Australia. The two species most commonly referred to in Australian literature are *E. dumosa* (*Macrantherae-Dumosae*) and *E. oleosa* (*Platyantherae-Subulatae*). In both these the circumscription of the species has been the subject of considerable attention and opinions differ as to the amount of morphological variation which should be included under the specific names (Gardner & Watson 1950; Burbidge 1947). This makes it difficult to define the areas of distribution, but if a wide circumscription is accepted, they extend from the drier areas of southern Western Australia to similar areas in eastern Australia.

It is evident from the distribution indicated above that mallees occur in a number of ecological habitats though they are absent from the higher rainfall zones except where the edaphic conditions are unfavourable for the development of forest. However, the "Mallee" association, as understood by ecologists, is characteristic of the drier parts of the winter rainfall belt, *i.e.*, between the wooded and forested areas of the coastal regions and the arid associations of the dry interior.

A ligno-tuber is found in many seedling Eucalypts and, under natural conditions, the young plants often have a shrubby form during the first few years. It is only later that one of the stems becomes predominant and grows out into the main trunk of the sapling. The most frequent adult form is the tree, but mallees and marlocks occur throughout the genus and such forms, in which many stems arise from ground level, may represent the retention of a juvenile state. There is no evidence that either mallees or marlocks are primitive in *Eucalyptus* since their chemical and morphological characteristics are not, at least in the case of the mallees, those which are usually regarded as primitive by most writers.

The sections of the genus generally considered to be the most primitive are the *Corymbosae* and *Eudesmieae*, though both exhibit a degree of specialisation which indicates that they cannot be taken as prototypic. In both groups the essential oils are high in pinene and low in cineol content (Baker & Smith 1920; Watson 1935-36). Leaves of the Bloodwood type (*i.e. Corymbosae*) are amongst the earliest known fossil remains of *Eucalyptus* (Cambage 1913). The nature of the essential oils, the leaf-venation, anther-type and, in some cases, the bark in the *Corymbosae* as well as the capsule form in the *Eudesmieae* show the closest affinities with *Angophora*. The *Corymbosae* nearly all have a tree form but some of the *Eudesmieae* are marlocks. Neither group includes any true mallees.

The scattering of mallee species through the genus is demonstrated in the above list and also in Table I below. In all cases the essential oils are low in pinene, and the cineol content varies from about 30 per cent. in some to 90 per cent. or more in the *Subulatae* (Gardner & Watson 1950). If the general conclusions drawn by Baker and Smith (*l.c.*) regarding the correlation between increasing oil complexity and development of the genus are accepted, then it is evident that mallees cannot be considered primitive. This is further substantiated by their morphology. Though the important group *Dumosae* is placed in the same antheral class as the above groups (Blakely 1934) the anthers and pollen grains are smaller and the leaf-venation and capsule-type show more specialisation and variation in form. In the remaining groups the anthers are specialised but the secondary nature is particularly shown in the *Subulatae* where the style is persistent and splits to form the characteristic fragile points on the valves in the matured fruit. This feature is not seen in any other *Eucalyptus* spp. and it has probably appeared comparatively late in the evolution of the genus.

Consequently it is the opinion of the writer that the mallee form represents a secondary development in the genus *Eucalyptus*.

It is possible that the marlocks and other shrubby forms are also of comparatively recent development, but the case is less clear. Blakely (1934) does not distinguish between mallees and marlocks so that not all of his common names can be accepted as indicative of the nature of the plant in the field, but marlocks are similarly scattered through the genus: *E. eudesmioides*, *E. tetragona* and *E. erythrocorys* (*Macrantherae-Eudesmieae*); *E. setosa*, which may be a low shrub in arid habitats (*Macrantherae-Corymbosae*); *E. tetraptera* (*Macrantherae-Tetrapterae*); *E. redunca* (*Macrantherae-Subcornutae*); *E. kruseana* (*Macrantherae-Globulares*) and *E. forrestiana* (*Platyantherae-Quadricostatae*). All these species except *E. setosa* are found in the drier areas of southern Western Australia. The fact that a number of marlocks are found in the *Eudesmieae* shows that secondary deviation cannot be argued on morphological grounds alone, but it may be significant that all occur in arid habitats as is the case with the majority of mallees, *i.e.*, they are found under climatic conditions which are unlikely to have been widespread in Australia during the Miocene when the major development of the genus probably took place.

TABLE I.

Distribution of the More Important Subgeneric Groups of Eucalyptus including Mallee Species (after Blakely).

—	Western Australia.				South Australia.				New South Wales.				Victoria.				Queensland.				Northern Territory.			
	Spp.		Var.		Spp.		Var.		Spp.		Var.		Spp.		Var.		Spp.		Var.		Spp.		Var.	
	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.	T.	R.
Dumosae	34	29	2	2	8	1	1	1	1	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..
Fruticosae	4	3	1	1	1	..	..	..	1	..	1	1	1	..	..	..	..	..	..	..	..	..	..	..
Aridae	3	1	..	..	2	..	1	2	1	..	2	1	2	..	..	..	..	..	..	..	..	..	..	..
Subulatae	8	5	..	..	5	1	3	2	5	1	..	..	2	..	1	..	2	1	..	..	2	1	..	..
Leptopodae	8	7	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Contortae	1	1	1	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

T = total; R = Restricted, *i.e.*, endemic so far as is known.

The question thus arises as to when these smaller forms—mallees and marlocks—were developed. Conditions during the Pliocene and Pleistocene were wetter than they are today and forests were more widely distributed but the pluvial conditions appear to have had an abrupt conclusion if Crocker and Wood (1947) are correct. According to these authors the change of climate at the end of the Pleistocene resulted in the destruction of much of the vegetation of Central Australia and the retreat of the Australian Element, of which *Eucalyptus* is so characteristic a constituent, to the coast, especially towards the south-west and south-east of the continent. They consider that there was an interim period, following the onset of aridity, during which biotypes capable of re-colonising the denuded areas were developed from the plants of the refugial areas.

If the present distribution of the rainfall belts is considered, it will be seen that the " Mallee " association is best developed in the areas between the zones to which the Pleistocene flora would have retreated and the more arid interior. Where mallee species, other than those found in the " Mallee," occur, there is always some qualifying feature, *e.g.*, the conditions peculiar to sand-dunes (*E. diversifolia*) or the shallow soils of the Hawkesbury Sandstone (*E. stricta*), where the change from the pluvial climate of the Pleistocene would have been locally marked in its effect on the existing flora. It is therefore suggested that a large number of the mallees and marlocks developed as a direct result of the climatic change at the end of the Pleistocene.

While some of the *Subulatae* extend into Central Australia, *e.g.*, *E. oleosa* var. *glauca* (*E. transcontinentalis*), west of Alice Springs, the paucity of mallees or marlocks in Northern Australia suggests that these types cannot have been widespread prior to the arid period. If mallees had previously existed in the interior then one would expect to find them more or less encircling the present arid region, *i.e.*, there would have been a coastward retreat in several directions rather than a southward retreat to produce the present southern arc. Also there is a lack of representatives in the refugial areas of Central Australia.

In Table I the distribution of the species most important in the " Mallee " association is shown under their various intra-generic groups. It will be noted that there is evidence that the centre of development lies in Western Australia and a check of the localities given by Blakely (1934) shows that they are mainly found in the southern Eremaean Province as defined by Gardner (1944). It is noteworthy that, whereas the eastern forms are almost all mallees, the western ones include trees both in the endemics and in widely distributed forms, *e.g.*, *E. oleosa*, *E. oleosa* var. *glauca* (*E. transcontinentalis*), *E. flocktoniae* and *E. gracilis*, though the last-named is seen as a small tree in the Murray Mallee of South Australia. From the figures there appears to be a secondary centre of speciation for *Eucalyptus*, particularly with regard to mallees, in the southern Eremaea, and the eastern forms with their more pronounced mallee habit may have migrated from this western centre despite the edaphic barrier of the Nullarbor Plain. If so the migratory route probably passed to the north of the plain through country where there are now scattered patches of " Mallee " (Wood 1929 ; Giles 1889).

This view is in direct opposition to that of Crocker and Wood (1947), since they consider *E. oleosa* and *E. gracilis* as having existed in refugia during the worst of the arid period to expand later into their present areas. If they are correct then these species would have retreated to the outer fringe of the South-Western Province in Western Australia and to the Flinders Range in South Australia, and the former area could still have produced the species of the southern Eremaea. This, however, presupposes that the relics in the Flinders Range, in contrast to the western representatives, retained a minimum amount of inherent variability since there are no well marked endemics in that area today. This is unlikely as the Eucalypts of the Flinders Range show considerable variation especially in the cases of *E. oleosa* and *E. dumosa* (Burbidge 1947). A better explanation than that given by Crocker and Wood is that these mallees originated in the west and are undergoing further segregation elsewhere. Furthermore the lack of climatically probable refugia and of endemics makes it unlikely that the mallees of New South Wales and Victoria included in the groups in Table I are either survivals from an earlier period or the original stock from which the others arose.

The distribution of the *Dumosae* strongly supports the above view, but the inclusion in the *Subulatae* of *E. umbrawarrensis* from near Pine Creek in the Northern Territory and *E. pachycalyx* from near Cairns in North Queensland raises certain difficulties. Quite apart from their distribution however, their morphological characters make it extremely doubtful if they are correctly placed in the *Subulatae.* It is more likely that they represent an offshoot from the same platyantherous stock as that from which the southern *Subulatae* arose. *E. bakeri* in northern New South Wales and south-eastern Queensland seems to be related closely to *E. oleosa* (*sens. lat.*) and may be a geographic race. The affinities of *E. squamosa,* which grows in certain parts of the Hawkesbury Sandstone in New South Wales, deserve further study. It is platyantherous, but the capsules and their valves are not particularly typical for the *Subulatae.*

A recent paper by Gentilli (1949) includes information which appears to support the idea of a western origin for the mallees dealt with in Table I. Both the Ring-necked Parrot (*Barnardius zonarius*) and the Sitella (*Neositta pileata*) are presumed to have migrated from a centre in the South-West Province of Western Australia and to have reached at least the longitude of the Flinders Range before coming into contact with other races of the same species. It is inferred that these migrations are recent, *i.e.*, since the arid period. Similar conclusions with regard to the Sitellas are reached independently by Mayr (1950). The migration of these birds could have been contemporaneous with and partly dependent upon the spread of the mallees, which would have provided nesting and feeding sites. The only alternative ecological association through which they could have passed would have been the Mulga (*Acacia aneura*), but at present Ring-necked Parrots are comparatively rare in Mulga areas. The importance of the Mallee-Mulga boundary in the distribution of birds has been stressed by Serventy and Whittell (1948) so that a route through the Mallee is more probable.

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OPISTHIOLEPIS, A NEW GENUS OF PROTEACEAE FROM QUEENSLAND.

By L. S. Smith, Queensland Herbarium, Botanic Gardens, Brisbane.

(With Plate IV.)

(Issued separately, 29th August, 1952.)

SUMMARY.

A new genus of the Proteaceae is described and a new transfer made.

The high degree of endemism in the rain-forest flora of north-eastern Queensland, despite the predominance of Malaysian genera, has already been remarked upon by the late C. T. White (1930, p. 234). One peculiar feature of this flora is that up to the present six monotypic genera of Proteaceae have been recorded, namely, *Austromuellera*, *Buckinghamia*, *Cardwellia*, *Carnarvonia*, *Musgravea*, and *Placospermum*. To these must now be added *Hollandaea* and *Opisthiolepis*. C. T. White, in manuscript, proposed the following transfer—

Helicia lamingtoniana (F. M. Bail.) C. T. White comb. nov.

Hollandaea Lamingtoniana F. M. Bail. in Queensl. Agric. Journ. **5** : 390 (1899).

The only accepted species of *Hollandaea* is now *H. sayeri* F. Muell. *Opisthiolepis*, described below, raises the number of genera, with Queensland representatives, in the tribe Embothrieae to seven.

Opisthiolepis L. S. Smith : genus novum in tribu *Embothriearum* ponendum ; inter genera hujus tribus squama hypogyna solitaria bidentata distinctum.

Flores hermaphroditi, parvi, incurvati, parum irregulares. *Perianthii* segmenta 4, inaequilonga, primum a latere abaxiali disjuncta, mox delapsa ; tubus obliquus, ± 4-angulatus, superne vix angustior ; limbus primum subglobosus, laminis concavis. *Stamina* 4, ad basin laminarum affixa ; filamenta complanata, lata, brevia, apicem versus in connectivum latum expansa ; antherae late ovatae. *Squama hypogyna* 1, adaxialis, oblonga, apice bidentata. *Ovarium* breviter stipitatum, 1-loculare ; ovula ca. 10-12, biseriatim imbricata, oblique disposita, medio vel supra medium lateraliter affixa. *Stylus* compressus, apice versus leviter constrictus deinde in discum oblique dilatatus, demum decurvatus ; stigma parvum, in medio disco. *Folliculus* (pauci delapsi solum visi) recurvus, breviter stipitatus, demum expansus, sublignosus, subplanus, apice leviter recurvus, bilobatus. *Semina* ignota.—Arbor. Folia alterna, in ramis fertilibus integra, sterilibus plerumque simplicia pinnataque interdum sparse dentata. Racemi axillares, tenues, spiciformes. Flores parvi, brevissime pedicellati, per paria bractea parva caduca suffulti.

Species 1, Australiae septentrionali-orientalis incola.

O. heterophylla L. S. Smith, species nova. Plate IV.

Arbor mediocris vel alta (usque ad 30 m. sec. Hanson). *Ramuli* juniores appresse ferrugineo-tomentosi, leviter angulati vel rotundati, vetustiores lenticellis parvis pustulatis dense notati. *Folia* dimorpha, simplicia vel pinnata; foliorum simplicium lamina coriacea, ovata vel oblongo-elliptica (4-) 7-15·5 (-30) cm. longa, (1·6-) 2·6-7 (-10·5) cm. lata, apice obtusa vel breviter acuminata, mucronulata, basi angustata, supra appresse pubescens, mox glabrata, subtus indumento minuto denso appresso nitente ferrugineo vel demum ± argenteo vestita, margine integra vel interdum sparse dentata, nervo medio subtus valde prominente, nervis lateralibus prominulis ca. 10-18 utroque latere; petiolus primum appresse tomentosus, ca. 1·2-3 (-5) cm. longus, supra canaliculatus, subtus rotundatus, basi incrassatus; foliorum pinnatorum 28-50 cm. longorum pinnae 5-18, quoad indumentum nervatioque foliis simplicibus similes, lanceolatae vel oblongo-lanceolatae (4·4-) 7·6-16·4 cm. longae, 1·9-3·8 cm. latae (vel harum terminalis interdum major), apice acutae vel acuminatae, mucronulatae, basi inaequilaterales, margine integrae vel sparse dentatae, petiolulatae petiolulo usque ad 8 mm. longo decurrente vel interdum superiores sessiles; petiolus 4·4-7·6 cm. longus, cum rhachi supra canaliculatus subtus rotundatus. *Racemi* axillares, spiciformes, laxiflori, simplices, solitarii vel interdum geminati, ferrugineo-tomentosi, 3-9 cm. longi; bracteae extus tomentosae, intus glabrae, ca. 0·9 mm. longae, emarginatae vel obtusae, caducae. *Flores* glabri, ca. 2·5-3·2 mm. longi, brevissime pedicellati pedicellis 0·25-0·6 mm. longis per paria bractea ± abditis; perianthii limbus subglobosus, ca. 1 mm. longus, tubus limbo angustior, segmenta inaequilonga horum lateralia falcata ca. 3 mm. longa, abaxiale ca. 5 mm. longum, adaxiale ca. 1·7 mm. longum; stamina parva, filamentis 0·1-0·3 mm. longis, antheris ca. 0·5 mm. longis, 0·5-0·6 mm. latis; squama hypogyna oblonga, 0·8 mm. longa, 0·5 mm. lata, basi crassior, apice bidentata; ovarium compressum, ca. 1 mm. longum, 10-12-ovulatum, stipite ca. 0·3 mm. longo praeditum; stylus ca. 2 mm. longus. *Folliculus* (post dehiscentiam) breviter stipitatus stipite ca. 6 mm. longo, ± applanatus, 5-6 cm. longus, medio 3-4 cm. latus, 1·5-2·0 mm. crassus.

QUEENSLAND. Cook District: Atherton, *C. T. White* (sterile), January 1918 (Local name "Silver Oak"); Atherton, *A. G. Hanson* 21/1 (TYPE—flowers), February 1950 (Specimen from a small rain-forest tree, which attains 100-110 ft. in height and 90 ins. g.b.h.; pinnate leaves absent on fertile branchlets); Malanda, *C. T. White* (sterile), January 1918 (Local name "Silver Oak"); Millaa Millaa, *J. King* 10 (sterile), March 1951; Paronella Park, Mena Creek, *ca.* 14 miles S. of Innisfail, alt. *ca.* 50 ft., *L. S. Smith* PP. 41 (old fruits) 4 August 1948 (A small slender tree *ca.* 20 ft. high near the creek bank; leaves often both pinnate and simple on the one branchlet, shiny brown or occasionally silvery beneath). North Kennedy District: Koolmoon Creek, *ca.* 11 miles SSE. of Ravenshoe, in rain-forest, alt. 2,400 ft., *L. S. Smith & L. J. Webb* 4583 (sterile), 29 September 1950 (A tree 70 ft. high, bole 1¼ ft. d.b.h., slightly channelled at the base. Bark 3/16-¼ in. thick; outer—light brown, marked by fine, broken, slightly reticulating, longitudinal lines of lenticels; inner—dark red on the outside, pinkish brown within with numerous fine, pale cream-coloured radial lines, when blazed showing a very pale cream or faintly purplish tinged honeycomb-like network, with brownish flecks, sometimes surrounded by pink, in the centre of the cells. Sapwood 1½ ins. thick, cream for ½ in., then pale pink for about 1 in.; heartwood light pinkish brown); Kirrama Range, west of Kennedy, in rain-forest between Society Flat and Yuccabine Creek, alt. *ca.* 1950 ft., *L. S. Smith & L. J. Webb* 3200 (sterile), 1 August 1947 (A small tree 45 ft. high, trunk 7 ins. diam. Outer bark brownish, marked by short, irregular, longitudinal, lenticellate lines with scattered, short, horizontal cracks between them, here and there with coarse red-brown pustules; inner bark $\frac{1}{8}$ in. thick, dark red on the outside, reddish brown within. Wood cream for $\frac{1}{2}$ in., becoming darker pink inwards. Leaves simple or pinnate, brownish or greyish beneath).

The genus resembles *Lomatia* in general structure, but is readily distinguished by the occurrence of a single hypogynous scale in the flower instead of three glands. Further, the dehisced follicles of the Queensland species of *Lomatia* are almost flat or very shallowly boat-shaped, often more or less beaked and not recurved at the apex, much thinner and of a less woody texture. Other differences may be apparent when the seeds of *Opisthiolepis* are known, although the ovules are very similar to those of *Lomatia*.

Opisthiolepis heterophylla, especially when young, is quite a showy tree and worthy of cultivation. The foliage comprises mixed leaf-types, is a bright green above and shiny brown or silvery beneath. The indumentum of the leaf-undersurface is somewhat similar to that of *Grevillea pinnatifida* F. M. Bail. or occasionally *G. hilliana* F. Muell. The juvenile or intermediate leaves, whether simple or pinnate, occasionally bear a few small teeth which, however, appear to be absent from the simple leaves on fertile branchlets.

I have seen trees in rain-forests from near Cardwell in the south to Mossman in the north and growing at altitudes of from approximately 50 ft. to 2,500 ft., though nowhere of very large dimensions. However, Mr. A. G. Hanson, Forester, Atherton, states that they grow to a height of 100 ft., the bole attaining $2\frac{1}{2}$ ft. in diameter, and therefore of commercial size.

The small, inconspicuous, almost sessile flowers may account for flowering specimens not having been collected in the past, and I am much indebted to Mr. Hanson for diligently searching for and collecting the only flowering specimens so far obtained.

[*L. S. Smith & L. J. Webb* 4853, since collected from Lacey's Creek, Mission Beach area, shows in addition that the flowers are white and that the lower racemes are pendulous, attain 15 cm. in length, and are sometimes branched. Old fruits similar to those described were obtained from the ground beneath the tree.]

The generic name is derived from the two Greek words ὀπίσθιος, hinder, and λεπίς, a scale, and refers to the adaxial, solitary, hypogynous scale in the flower.

REFERENCE.

White, C. T., 1930. A new genus of Proteaceae from North Queensland. Kew Bull. **1930**, No. 6: 234-5.

Opisthiolepis heterophylla L. S. Smith. 1, portion of flowering branchlet x 2/3 ; 2a and 2b, two types of compound leaf x 1/6 ; 3, flower-bud x 10 ; 4, flower x 10 ; 5, pistil and hypogynous scale after perianth-segments have fallen x 10 ; 6, hypogynous scale x 10 ; 7, apex of style with stigma x 10 ; 8, longitudinal section of ovary x 10 ; 9, two ovules after fertilisation x 16 ; 10, tip of lateral perianth segment showing position of stamen x 10 ; 11, back view of anther from abaxial perianth segment x 10 ; 12, tip of adaxial perianth segment x 10 ; 13, side view of dehisced follicle x 1 ; 14, back view of dehisced follicle x 1.

THE IDENTIFICATION AND DISTRIBUTION OF SOME CYPERACEAE AND GRAMINEAE, CHIEFLY FROM AUSTRALIA.

By S. T. Blake, Queensland Herbarium, Botanic Gardens, Brisbane.

(With Plates V and VI.)

(Issued separately, 29th August, 1952.)

SUMMARY.

The identification, nomenclature and distribution of some Cyperaceae and Gramineae are discussed. Six species are new records for Australia, one for both Queensland and South Australia, and two for Queensland, while six new species are described.

Many sedges and grasses found in Australia are also found over a wide area beyond Australia. The identification of these " wides " is often a serious difficulty which can only be solved by the study of types of all the names of allied species, many of which are not readily available. The loan of several such types from the herbaria at Lund (LD), Paris (P) and Copenhagen (C) has been made to me through the kindness of Dr. A. Hässler, Prof. H. Humbert and Dr. O. Hagerup respectively, and I wish to express my gratitude to them for their assistance. Miss M. B. Tindale and Mr. E. Nelmes have kindly copied passages from publications in the library of the Kew Herbarium which are unavailable in Australia. Some of the species studied are discussed in this paper; the opportunity has been taken to record extensions to the previously known range of some allied endemic species, to describe some new ones, and to correct an error in nomenclature.

Cyperaceae.

Cyperus sulcinux C. B. Clarke in J. Linn. Soc. **21** : 56 (1884).

Queensland.—North Kennedy District: Bowen, near roadside in granite sand, 25th Sept. 1950, *Blake* 18544.

New for Australia; widely spread through Malaysia to India and Indo-China. The collection cited above consists of a large number of small plants with culms 1-7 cm. high and the wide-spreading rays of the inflorescence up to 5·5 cm. long below the rich brown spikelets. The species belongs in subgenus *Pycreus* and its chief distinguishing characters are its annual habit, very obtuse glumes closely 3-nerved on the back with nerveless sides, and oblong nut with a shallow furrow down each face.

Scirpus L. Sect. **Actaeogeton** Reichb. Ic. Fl. Germ. et Helv. 40 (1846); Beetle in Amer. J. Bot. **29** : 653-6 (1942).

This section is based on *Scirpus mucronatus* L. and its characteristic features are that the culms are nodeless above the base or have but one node in the lower part, the leaves are commonly reduced to more or less mucronate sheaths, the outer involucral bract appears like a continuation of the culm, and the black or dark-brown or grey-brown nut is marked by transverse, wavy ridges; there may be two or three stigmas and hypogynous bristles may be present or absent; some species regularly produce flowers in the leaf-sheaths with greatly elongated styles and stigmas. Difficulties which had been encountered when studying the Australian members of this group were not solved by the application of Beetle's revision cited above. The following discussion is offered as a contribution towards a better understanding of the species which have been associated in one way or another with the name *S. supinus* L. The names and more important references which must be considered are as follows :—

Eleocharis juncoides (Roxb.) Schult. Mant. **2** : 90 (1824).

Isolepis ambigua Steud. in Zoll. Verz. Ind. Arch. heft 2 : 62 (1854) ; C. B. Clarke in Philip. J. Sci. **2,C** : 99 (1907).

Isolepis ambigua Steud. Syn. Cyp. 91 (1855).

Isolepis (?) *juncoides* (Roxb.) Miq. Fl. Ind. Bat. **3** : 312 (1856).

Isolepis oryzetorum Steud. Syn. Cyp. 96 (1855) ("*oryectorum*").

Isolepis polycolea (Notaris) Steud. Syn. Cyp. 95 (1855).

Isolepis proxima Steud. Syn. Cyp. 95 (1855).

Isolepis supina (L.) R. Br. Prodr. 221 (1810) ; Nees in Wight Contrib. Bot. Ind. 108 (1834).

Isolepis uninodis Delile Fl. Egypt. 8, *t.* 6, *fig.* 1 (1812).

Scirpus cernuus Vahl Enum. **2** : 245 (1806) ; Bedevian, Illustrated Polyglottic Dictionary of Plant Names 535 (1936).

Scirpus dissachanthus S. T. Blake in Vict. Nat. **63** : 116 (1946).

Scirpus erectogracilis Hayata Ic. Pl. Formos. **6** : 114 (1916).

Scirpus erectus Poir. Encycl. **6** : 761 (1804) ; C. B. Clarke in Hook.f. Fl. Brit. Ind. **6** : 656 (1894) ; Cherm. in Arch. Botanique **4** (7) : 26 (1931) ; Beetle in Amer. J. Bot. **29** : 654 (1942).

Scirpus hallii Gray Addenda Man. ed. 2 (1863).

Scirpus junciformis Nees in Wight Contrib. Bot. Ind. 112 (1834) ; nec Retz. (1791) nec (H. B. K.) Poir. (1817).

Scirpus juncoides Roxb. Hort. Bengal. 81 (1814), *nomen nudum* ; Fl. Ind. **1** : 228 (1820), ed. Carey **1** : 216 (1832) ; non Willd. ex Kunth (1837).

Scirpus lateralis Forsk. Fl. Aegypt.-Arab. 15 (1775) ; Vahl Enum. **2** : 280 (1806) ; Spreng. Syst. Veg. **1** : 207 (1825) ; C. B. Clarke in Prain Fl. Trop. Afr. **8** : 453 (1902), *in syn.* ; Christens. in Dansk Bot. Arkiv **4** : 12 (1922).

Scirpus lateralis Retz. Obs. **4** : 12 (1786) ; Nees in Wight Contrib. Bot. Ind. 108 (1834), *in syn.* ; C. E. C. Fischer in Kew Bull. **1932** : 70 (1932).

Scirpus lateriflorus Gmel. Syst. 127 (1791).

Scirpus luzonensis Presl Rel. Haenk. **1** : 193 (1828).

Scirpus oryzetorum (Steud.) Ohwi in Mem. Coll. Sci. Kyòto Imp. Univ. ser. B, **18** (**1**) : ? (1944).

Scirpus polycoleus Notaris in Ann. Sci. Nat. III, **9** : 326 (1848).

Scirpus supinus L. Sp. Pl. 49 (1753) ; Benth. Fl. Austral. **7** : 330 (1878) ; C. E. C. Fischer in Kew Bull. **1932** : 70 (1932).

Scirpus supinus L. var. *digynus* Boeck. in Linnaea **36** : 700 (1870).

Scirpus supinus L. var. *digynus* Boiss. Fl. Orient. **5** : 380 (1884).

Scirpus supinus L. var. *elatior* Boeck. in Linnaea **36** : 700 (1870).

Scirpus supinus L. var. *hallii* (Gray) Gray Man. Bot. N. U.S. ed. 5, 563 (1867).

Scirpus supinus L. var. *uninodis* (Delile) Asch. & Schweinf. Ill. Fl. d'Égypte 157 (1887) ; Christens. in Dansk Bot. Arkiv **4** : 12 (1922).

Scirpus supinus L. var. *uninodis* (Delile) C. B. Clarke in Hook.f. Fl. Brit. Ind. **6** : 656 (1894) et in Prain Fl. Trop. Afr. **8** : 453 (1902).

Scirpus timorensis Kunth Enum. **2** : 162 (1837).

Scirpus uninodis (Delile) Beetle in Amer. J. Bot. **29** : 656 (1942) (*author wrongly cited*), in Amer. Midl. Nat. **34** : 734 (1945) ; S. T. Blake in Vict. Nat. **63** : 119 (1946) (*author wrongly cited*).

Scirpus uninodis (Delile) " Boiss." var. *hallii* (Gray) Beetle in Amer. J. Bot. **29** : 656 (1942).

The earliest of these names is *S. supinus*, which was based on European specimens. Most of the other names were proposed for plants from other parts of the world, some of which were originally carefully distinguished from *S. supinus*, but most of which have been considered by one botanist or another to be conspecific with *S. supinus* or only varietally distinct from it.

S. lateralis Forsk. was described from a plant collected by Forskahl in Arabia, to the north-west of Aden. The specimen was lost prior to 1806 (Vahl, 1806) and has not been found since (Christensen, 1922 ; Hagerup, *in litt.*). Sprengel (1825) thought that Forskahl's plant was conspecific with the later described *Isolepis uninodis* Delile ; at one time, C. B. Clarke (1902) followed this opinion and Christensen (1922) was inclined to agree. Otherwise the species has been usually ignored or placed among the doubtful species. Forskahl's description is brief and does not mention flower or fruit. So far as it goes, it could apply to specimens of *Isolepis uninodis* except for the longer and apparently more numerous rays of the inflorescence and the leafy base ; also it would apply to *Scirpus litoralis* Schrad. (the only other species which I have found recorded from Arabia) except that the height " pedalis & saepe cubitalis " is much less than is usual for the species. The phrase " basi foliosa " does not very well apply to either species unless sterile culms are meant, but *S. litoralis* does sometimes produce conspicuous basal leaves. The Arabic name quoted by Forskahl and transliterated by him " hallâl " (better, " hhalâl ") is applied to *S. cernuus* in Egypt according to Bedevian (1936), but Forskahl's description certainly does not apply to this species. From the available evidence, slight as it is, it appears that Forskahl's name does not refer to *Isolepis uninodis*, but may refer to *Scirpus litoralis*.

From a specimen collected in Ceylon by Koenig, Retzius described a species which he also called *Scirpus lateralis*, apparently in ignorance of Forskahl's earlier use of the name. Gmelin altered Retzius' name to *Scirpus lateriflorus*, apparently because it was a later homonym. *Scirpus lateralis* Retz. was referred to *Isolepis supina* (L.) R.Br. (*Scirpus supinus* L.) by Nees (1834) and to *Scirpus supinus* L. by C. E. C. Fischer (1932), but otherwise it and *S. lateriflorus* appear to have been usually ignored.

Scirpus erectus Poir. was based on a specimen collected by du Petit Thouars in Mauritius (Madagascar was quoted in the original description, but the locality on the label is " Ile de France "). This name was misapplied by C. B. Clarke (1894 and elsewhere) and by Beetle (1942) to a species quite distinct from that represented by Poiret's type. Neither Clarke nor Beetle included Mauritius in the range of *S. erectus*, yet Clarke saw Poiret's type and annotated it " Scirpus supinus Linn. var. γ uninodis (sp.) Delile."

Isolepis uninodis Delile was based on an Egyptian plant. C. B. Clarke (1894, 1902) treated it as a variety of *Scirpus supinus* and the ternary combination has been commonly cited as *S. supinus* L. var. *uninodis* (Delile) C. B. Clarke in Hook.f. Fl. Brit. Ind. 6 : 656 (1894), although the combination had been published earlier, though rather carelessly, by Ascherson and Schweinfurth (1887). Chermezon (1931) treated *Scirpus erectus* and *Isolepis uninodis* as synonymous and pointed out that Clarke had misapplied Poiret's name to a species of which the correct name is *S. juncoides* Roxb. In the synonymy, Chermezon quoted " Trabut " as the author of the combination *Scirpus uninodis,* but no evidence for this has been found by me or by Mr. E. Nelmes who kindly made a search for it. Beetle treated *Isolepis uninodis* as a distinct species of *Scirpus,* citing the name as *Scirpus uninodis* (Delile) Boiss. Fl. Orient. 5 : 380 (1884), but in actual fact Boissier treated it as a variety of *S. supinus* (*S. supinus* L. var. *digynus* Boiss.) and cited as a synonym (the basonym) " S. uninodis Del. Descr. Eg. p. 132 sub *Isolepide* tab. 6, fig. 1." Actually, Beetle himself made the transfer and he correctly cited the author in a later paper (Beetle, 1945) but without reference to the place of publication. He gave " Eurasia " as the range of the species, although Egypt is the type locality, and followed C. B. Clarke in misapplying the name *S. erectus* to *S. juncoides.* I followed Beetle by citing *S. uninodis* (Delile) Boiss. when *S. dissachanthus* was described and its affinities discussed (Blake 1946).

" *Isolepis ambigua* Steud. ! in Zoll. Verz. Ind. Archip. heft 2, 62 " was cited by C. B. Clarke (1907) as a synonym of *S. supinus* var. *uninodis* ; this is a *nomen nudum,* while the description of *I. ambigua* Steud. Syn. Cyp. 91 refers to a very different species from those discussed in this paper.

Isolepis oryzetorum Steud. was based on specimens from Java ; the epithet was spelled " *oryectorum,*" but this is an evident " unintentional orthographic error " (there are other misprints on the page) and the epithet was correctly spelled in the index.

Among the numerous specimens and other material examined, the following were of particular importance in interpreting the names mentioned above:—

The type of *Scirpus lateralis* Retz. and consequently of *S. lateriflorus* Gmel. (LD) ; a rubbing and piece of the type of *Scirpus erectus* Poir. (P) ; a tracing of Delile's excellent plate and a copy of his elaborate description of *Isolepis uninodis* (BRI) on which name *Scirpus supinus* var. *digynus* must be typified ; topotypes of *Isolepis oryzetorum, Scirpus luzonensis, Scirpus supinus* and *Scirpus timorensis* ; and the original figure and description of *Scirpus erectogracilis.* Three distinctive species can be recognised, all with slender, non-septate culms and very long lower involucral bracts. They may be distinguished as follows :—

Culms nodeless above the base, without flowers in the leaf-sheaths ; involucral bract solitary ; spikelets always sessile, usually few, rarely solitary ; glumes many-striate with glabrous margins ; nut obovate in outline :

> Annual plants with black, rather sharply trigonous, prominently transversely wavy-ridged nuts and no hypogynous bristles ; leaf-blades well-developed . . . . *S. supinus*
>
> Perennial plants with brown, plano-convex, faintly wavy-ridged nut and 6 well-developed, retrorsely scabrous, hypogynous bristles ; leaf-blades rudimentary . . . . *S. juncoides*

Culms with a node well above the base; leaf-blades rudimentary; solitary flowers in the leaf-sheaths with long-exserted stigmas; 2 involucral bracts usually present, the second one short; some spikelets peduncled but the peduncles sometimes very short; glumes 3-1-nerved, prominently keeled, minutely ciliolate on the upper margins; nut suborbicular in outline, plano-convex to trigonous, black when ripe, faintly to conspicuously transversely wavy-ridged .. .. *S. lateriflorus*

S. supinus appears to be confined to Europe; its complete synonymy has not yet been worked out. The synonymy and distribution of the other two species follow :—

Scirpus lateriflorus Gmel. Syst. 127 (1791).

Scirpus lateralis Retz. Obs. **4**: 12 (1786), non Forsk. (1775).

Scirpus erectus Poir. Encycl. **6**: 761 (1804).

Scirpus polycoleus Notaris in Ann. Sc. Nat. III, **9**: 326 (1848).

Scirpus supinus L. var. *digynus* Boiss. Fl. Orient. **5**: 380 (1884), non Boeck. (1870).

Scirpus supinus L. var. *uninodis* (Delile) Asch. & Schweinf. Ill. Fl. d'Égypte 157 (1887).

Scirpus supinus L. var. *uninodis* (Delile) C. B. Clarke in Hook.f. Fl. Brit. Ind. **6**: 656 (1894).

Scirpus erectogracilis Hayata Ic. Pl. Formos. **6**: 114 (1916).

Scirpus oryzetorum (Steud.) Ohwi in Mem. Coll. Sci. Kyoto Imp. Univ. ser. B, **18** (1): ? (1944).

Scirpus uninodis (Delile) Beetle in Amer. J. Bot. **29**: 656 (1942) (*author wrongly cited*) et in Amer. Midl. Nat. **34**: 734 (1945).

Isolepis uninodis Delile Fl. Egypt. 8, *t.* 6, *fig.* 1 (1812).

Isolepis polycolea (Notaris) Steud. Syn. Cyp. 95 (1855).

Isolepis oryzetorum Steud. Syn. Cyp. 96 (1855) (" *oryectorum* ").

? *Isolepis proxima* Steud. Syn. Cyp. 95 (1855).

S. lateriflorus is widely spread in the tropics and subtropics of Africa, Asia and Australia, chiefly in rice-fields, at the edges of swamps and streams and on the beds of drying-out lagoons and water-courses. The following specimens have been examined in various herbaria :—

AFRICA.—EGYPT (tracing of Delile's figure of *Isolepis uninodis* Delile). MAURITIUS, *du Petit Thouars* (type of *Scirpus erectus* Poir.).

ASIA.—INDIA : Eastern India, *Wight* 2893. CEYLON : Ganorawa, in rice-field, Sept. 1926, *Alston* 318 ; without definite locality, *Koenig* (type of *Scirpus lateralis* Retz. and *S. lateriflorus* Gmel.). FORMOSA : (Original figure of *S. erectogracilis* Hayata). MALAYA : Kedah, Kepala Batas, Nov. 1941, *Corner in Singapore Field No.* 38108; Langkaw, rice-fields near Kuah, Nov. 1941, *Corner in Singapore Field No.* 37975. PHILIPPINE ISLANDS: Pangasinan Province : Alaminos, Dec. 1922, *McGregor in Bureau of Science No.* 41456. Bulacan Province: Manila and vicinity, Oct. 1913, *Ramos in Bureau of Science No.* 21970, and without exact locality, Sept. 1913, *Ramos in Bureau of Science No.* 1441 *partly.* JAVA : Without definite locality, *Ploem* ; Gĕnĕng, 28th May 1913, *Haarsveld* ; Redzoso, E. of Pasoeroean, 10th June 1924, *Kooper* ; (topotypes of *Isolepis oryzetorum* Steud.). SOEDHONO : Without definite locality and without collector's name, 19th June 1925. LOMBOK : Pangantap, coast, July 1909, *Gründler* 2377.

AUSTRALIA.—Western Australia: Kimberley Division: Isdell R., 5 miles below Mt. Bartlett, July 1905, *Fitzgerald*; Lennard R., 10 miles above junction of Barker R., May 1905, *Fitzgerald* 588. Northern Territory: Fitzmaurice R., Oct. 1855, *Mueller*; 12° 43′ S., 131° 30′ E., dried-out depressions at edge of lagoon, 17th Sept. 1946, *Blake* 17033; near Rum Jungle and Finniss R., about 12° 59′ S., 130° 58′ E., wet sandy creek bank, 55 m., 8th August 1946, *Blake* 16728; Mary R., about 13° 5′ S. and 131° 47′ E., muddy bank, about 55 m., 28th Sept. 1946, *Blake* 17088; about 14° 7′ S., 131° 16′-18′ E., edge of open swamp, about 45 m., 1st July 1946, *Blake* 16273. Queensland: Burke District: Near Burketown, June 1943, *Whitehouse*; near Normanton, edge of fresh-water lagoon, 19th August 1936, *Blake* 12626; between Norman and Gilbert Rivers, *Gulliver*. Cook District: Endeavour R., *Banks & Solander*. North Kennedy District: Near Woodstock, S. of Townsville, on mud in drying-out *Melaleuca* swamp, 23rd Sept. 1950, *Blake* 18510; Pentland, edge of tank, 390 m., 12th June 1934, *Blake* 6148. Mitchell District: Geera, E. of Barcaldine, in fresh water at 270 m., 29th Nov. 1935, *Blake* 10337, and in wet places at end of bore-drain, 270 m., 6th Dec. 1935, *Blake* 10363. New South Wales: North Coast: Richmond R., *Woolls*. Central Coast: Centennial Park, Sydney, Feb. 1916, *Hamilton*. Victoria: Mallee: Lake Lalbert, *Mueller*; Dimboola, Jan. 1895, *Reader*.

Of the names cited at the beginning of this discussion, *S. hallii* Gray, *S. supinus* var. *hallii* (Gray) Gray and *S. uninodis* var. *hallii* (Gray) Beetle refer to a plant of the eastern United States. Beetle stressed the sharp ridges on the nut and its prominent mucro; it is evidently very close to *S. lateriflorus*, of which some Australian specimens have sharply ridged nuts, but I have not seen sufficient American material to form an independent opinion on its status.

Scirpus juncoides Roxb. Hort. Bengal. 81 (1814), *nomen nudum*; Fl. Ind. **1**: 228 (1820), ed. Carey **1**: 216 (1832); non Willd. ex Kunth (1837).

Scirpus luzonensis Presl Rel. Haenk. **1**: 193 (1828).

Scirpus junciformis Nees in Wight Contrib. Bot. Ind. 112 (1834); non Retz. (1791) nec (H. B. K.) Poir. (1817).

Scirpus timorensis Kunth Enum. **2**: 162 (1837).

Scirpus supinus L. var. *elatior* Boeck. in Linnaea **36**: 700 (1870).

Eleocharis juncoides (Roxb.) Schult. Mant. **2**: 90 (1824).

Isolepis (?) *juncoides* (Roxb.) Miq. Fl. Ind. Bat. **3**: 312 (1856).

This is the plant for which the name *Scirpus erectus* Poir. has been commonly used. It is a stouter plant than the species to which this name was originally applied (= *S. lateriflorus* Gmel.), with few, larger, ovoid, terete, sessile spikelets, tightly appressed, striate glumes keeled only near the broadly rounded and more or less mucronate tip and glabrous on the margins, well-developed hypogynous bristles, and more or less plano-convex brown nut which is only faintly rugose. It is widely spread and apparently common from India and China to Malaysia as far east as Timor.

Scleria sumatrensis Retz. Obs. **5**: 19 (1789).

Queensland.—Cook District: Yarrabah near Cairns, in swamp forest, 28th June 1935, *Blake* 9649; Innisfail, in *Pandanus* swamp, about 4·5 m., 28th Nov. 1941, *Blake* 14467.

New for Australia; widely spread through Malaysia to Ceylon and India, but not yet known from New Guinea. The type (LD) consists of an inflorescence with some immature fruit; the Australian specimens have paler spikelets. The species belongs to a group of closely allied coarse species which have the leaves in the middle part of the stem and the lower bracts clustered in false-whorls of 3, large inflorescences of several partial panicles, unisexual spikelets, and a 3-lobed disc; *S. sumatrensis* is distinguished by the tall disc which is from one-half to two-thirds as high as the nut.

Scleria terrestris (L.) Fassett in Rhodora **26**: 159 (1924).

QUEENSLAND: Cook District: Innisfail, in *Pandanus* swamp, about 4·5 m., 28th Nov. 1941, *Blake* 14468.

New for Australia; widely spread through Malaysia to China and Ceylon. It is a coarse species with scattered leaves, unisexual spikelets and a small disc with rounded short lobes.

Scleria poaeformis Retz. Obs. **4**: 13 (1786).

Scleria oryzoides Presl Rel. Haenk. **1**: 201 (1830); Benth. Fl. Austral. **7**: 432 (1878).

QUEENSLAND.—North Kennedy District: Cardwell, in *Melaleuca* swamps about sea-level, dominating with *Lepironia articulata* the wetter parts, 26th Sept. 1935, *Blake* 9700; Ingham, fairly common in open swamp, 5th Dec. 1942, *Blake* 14787.

New for Queensland; previously reported from the Northern Territory by Bentham, *l.c.*, under the name of *S. oryzoides* Presl. The type (LD) consists of an inflorescence only, which is matched by those of the Queensland specimens. The stout stems are rather distantly produced from a long-creeping rhizome and bear scattered, broad, more or less obtuse leaves and solitary, terminal, decompound panicles of chiefly male spikelets; female spikelets occur only towards the base of the branches in the lower part of the panicles. It is widely spread through Malaysia to India.

Gramineae.

Stipa nodosa S. T. Blake; species nova, affinis *S. scabrae* Lindl., sed culmis plurinodibus, foliis basalibus perpaucis, ligulis brevioribus glabrisque praecipue differt.

Gramen perenne, caespitosum, circa 1 m. altum. Culmi erecti, graciles, teretes, duri, leviter striati, dense granuloso-asperuli, glabri, pro more 5-8-nodes nodis incrassatis, simplices vel parce ramosi, basi cataphyllis paucis stramineis plus minusve sericeis cincti; innovationes perpaucae. Folia plerumque caulina, basalia perpauca; vaginae arctae, convolutae, striatae, asperulae, margine exteriore ciliatae, ore barbatae, nodis glabrae, internodiis breviores; auriculae incrassatae; ligulae truncatae, glabrae, 0·5-0·75 mm. longae; laminae rigidae, setaceae, convolutae vel involutae, acutissimae, minute scabridae, usque ad 30 cm. longae, explanatae usque ad 3·5 mm. latae, sursum nervis scabridae, inferiores gradatim minores. Panicula exserta, sublaxiflora, linearis, 20-30 cm. longa (aristis exclusis) et 4-6 cm. lata; axis communis pro majore parte teres laevisque, parte superiore plus minusve angulosa scabra, nodis (praecipue inferioribus) albo-pilosa; rami ad nodum quemque plures, unilateraliter fasciculati, tenuiter filiformes, suberecti vel patentes, fere ad medium nudi, longiores usque ad 6 cm. longi iterum ramulosi; pedicelli sursum scabridi, 4-10 mm.

longi. Spiculae lineares, purpurascentes. Glumae subaequales, 7-8 mm. longae, tenuiter membranaceae, lanceolatae, acutissime acuminatae, glabrae, carina percurrente sursum vix scabridae ceterum laeves ; inferior 3-nervis nervis lateralibus brevibus ; superior parum (usque ad 1 mm.) brevior, 5-nervis, nervis exterioribus brevioribus, intermediis cum nervo mediano supra medium anastomosantibus. Lemma demum fuscum, lineari-fusiforme, callo incluso 5-5·5 mm. longum, 0·7-0·8 mm. latum, puncticulatum, albo-pilosum, apice minute lobulato nudum ; callus 1·3-2 mm. longus, albo-barbatus, apice curvatus pungens. Arista gracilis, 45-50 mm. longa, scabrida ; columna 11·5-13 mm. longa, sursum flexuosa ; seta falcata, gracillima. Palea lemmate fere aequilonga, carinis longe pilosa. PLATE V.

SOUTH AUSTRALIA.—Flinders Ranges : In Parachilna Gorge between Blinman and Parachilna, at edge of Parachilna Spring, about 225 m., 1st Sept. 1946, *Blake* 16914 (TYPE) ; ENE. of Port Augusta in Pichirichi Pass, in mallee (chiefly *Eucalyptus gracilis*) - *Kochia* open scrub, 29th August 1946, *Blake* 16863.

Stipa nodosa closely resembles *S. scabra* in the structure of the inflorescence and spikelet, but it is entirely different in habit. The hard culms with usually 5-8 nodes and paucity of basal leaves and innovations in *S. nodosa* contrast sharply with the 3-4-noded, softer culms of *S. scabra* with their abundance of basal leaves and innovations ; the leaf-blades are less scabrous and more rigid, the ligule is much shorter and quite glabrous (not hairy on the back), the panicle is exserted rather early and not permanently included at its base in the uppermost leaf-sheath as in *S. scabra*, and the glumes and awns are slightly shorter. Each of the collections cited consists of several sheets with panicles in various stages of development. The plants in Pichirichi Pass were associated with *S. scabra* (*Blake* 16864).

Stipa brachystephana S. T. Blake ; species nova, affinis *S. aristiglumi* F. Muell., *S. bigeniculatae* Hughes et *S. blackii* C. E. Hubbard, sed ab omnibus ligulis elongatis glabris atque aristis brevioribus differt.

Gramen perenne, caespitosum, circa 70-90 cm. altum. Culmi erecti, teretes, leviter striatuli, dense granuloso-asperuli, glabri, 3-4-nodes, simplices, basi cataphyllis subsericeis fulvis vel brunnescentibus cincti. Foliorum vaginae arctae, convolutae, glabrae, laeves vel minute asperulae, superiores vel omnes internodiis multo breviores ; ligulae rigidae, striatae, glabrae, apice integrae vel saepe emarginatae vel tandem bifidae, 4-7 mm. longae, eae foliorum basalium gradatim breviores ; laminae setaceae, arcte convolutae quasi teretes, rigidiusculae, apice acutissimae sed vix pungentes, suberectae, longissimae, inferiores medium culmum superantes, superiores paniculam attingentes, minute asperulae vel laeves, supra pilosulae, marginibus scabridae, explanatae 0·8-1 mm. latae, eae foliorum basalium gradatim breviores. Panicula angusta, sublaxiflora, tandem longe exserta, aristis exclusis 13-15 cm. longa at 1·5-2·5 cm. lata ; axis communis inferne compressa sublaevis, sursum angulosa scabrida ; rami terni vel bini, usque ad 3·5 cm. longi, plus minusve erecti, usque ad medium pro more nudi, sursum parum divisi pauciflori ; pedicelli compresso-filiformes, scabri, 2-8 mm. longi. Spiculae primum fusiformes tandem plus minusve hiantes, purpurascentes. Glumae firme membranaceae, margines versus hyalinae, 5-nerves nervo medio plus minusve percurrente sursum scabro, 2 lateralibus circa mediam glumam evanescentibus, 2 exterioribus brevibus, sursum dorso scabridae, dorso admodum incurvae, explanatae lanceolatae, acuminatae saepe cuspidatae ; inferior 11-12 mm. longa ; superior 9-10 mm.

longa minus acuminata. Lemma oblanceolato-fusiforme, apice subabrupte acuminatum, apice integrum pilis albis usque ad 0·9 mm. longis coronatum, ceterum pilis longis albis dense vestitum, callo incluso 6·5-7 mm. longum, circa 1·2 mm. latum ; callus curvatus pungens, 1·6-1·8 mm. longus, pilis albis barbatus. Arista bigeniculata, scabra, 2·3-2·6 cm. longa ; seta recta, columnam fere adaequans vel quam ea distincte brevior. Palea lemma adaequans. PLATE VI.

SOUTH AUSTRALIA.—Flinders Ranges : Port Germein Pass, steep stony hillsides with scattered eucalypts and *Xanthorrhoea* sp., about 210 m., 29th August 1946, *Blake* 16858.

On account of the turgid spikelets with firm, prominently 5-nerved, bulging and upwardly incurved glumes, the prominently bearded tip of the lemma and the bigeniculate awn, this species appears to be most closely related to *S. aristiglumis* F. Muell., *S. bigeniculata* Hughes and *S. blackii* C. E. Hubbard, but the very long glabrous ligule (sometimes split to the base) and relatively short awns and panicle-branches sharply distinguish it from all three. The glabrous nodes further distinguish it from *S. bigeniculata* and *S. blackii* and the nearly smooth and glabrous leaves and shorter tuft of hairs at the apex of the lemma still further distinguish it from *S. blackii*. *S. brachystephana* and *S. blackii* were found growing in association, but the hairy leaves and longer panicle-branches of *S. blackii* provided a ready means of distinguishing them in the field.

Echinochloa stagnina (Retz.) Beauv. Agrost. 161 (1812).

Panicum stagninum Retz. Obs. **5** : 17 (1789).

WESTERN AUSTRALIA.—Kimberley Division : Milligan's Lagoon near Wyndham, 10th April 1950, *Langfield* 211.

QUEENSLAND.—Cook District : Forest Home Station, very abundant in swamps, April 1931, *Brass* 1886.

New for Australia ; widely distributed in the tropics of the Eastern Hemisphere and considered an excellent pasture grass in Tropical Africa. The Australian specimens differ from the type (S. India, *Koenig*—LD) in having a scarcely hispid lower glume and a much longer awn to the lower lemma, but both these characters are variable in this species.

Echinochloa walteri (Pursh) Heller Cat. N. Amer. Pl. ed. 2 : 21 (1900).

Panicum hirtellum Walt. Fl. Carol. 72 (1788), non L. (1759).

Panicum walteri Pursh Fl. Amer. Sept. 66 (1814).

QUEENSLAND.—Wide Bay District : Stony Creek near Bundaberg, 2nd Jan. 1939, *Goy & Smith* 631 ; Bingera Weir near Bundaberg, along river bank, 30th Dec. 1937, *Smith* 407 ; near Mapleton, on more or less open muddy bank of small stream about 150 m., 14th April 1940, *Blake* 14176. Moreton District : North Pine R., Petrie, in mud at water's edge, 26th Dec. 1930, *Blake* 91 : Brisbane R., *Bailey* ; Holland Park, near Brisbane, common on outskirts of shallow waterhole full of *Leersia hexandra* and *Phragmites communis*, 15th Feb. 1938, *Smith* 290 ; Ekibin, Brisbane, 8th May 1909, *White* ; Samford Creek, common in soft mud on edge of creek, 29th March 1936, *Goy* 115 ; Enoggera, 17th May 1915, *White* ; Wellington Point, March 1916, *White* ; Currumbin, in a heap of road sand by the roadside, 10th Dec. 1932, *White* 8739 ; foot of Mt. Gipps (McPherson Range), in a gully, about 210 m., 11th April 1941, *Blake* 14319. Darling Downs District : " Merivale " near Injune (no collector's name).

New South Wales.—North Coast: Lynch's Creek, in wet gullies in *Eucalyptus* forest, 15th March 1944, *White* 12599.

New for Australia; native of the eastern United States. The Australian specimens correspond to forma *laevigata* Wiegand with almost glabrous sheaths.

The Australian species of *Echinochloa* may be distinguished as follows:—

Ligule represented by a fringe of hairs:
- Spikelets much narrower than long, rather gradually acuminate and distinctly awned .. .. .. *E. stagnina* (Retz.) Beauv.
- Spikelets nearly as broad as long, abruptly acuminate and cuspidate but not awned .. .. .. *E. turneriana* Domin

Ligule represented by a discoloured zone only:
- Lower glume and upper lemma equally acute or cuspidulate; racemes 3-4-seriate, ± erect .. .. *E. colonum* (L.) Link
- Lower glume and upper lemma cuspidate or produced into an awn, the latter more so than the former; racemes ± spreading:
  - Inflorescence ± erect, with awns up to 10 mm. long or spikelets awnless; leaf-sheaths with a few long hairs on the margins or glabrous:
    - Spikelets ± awned, ± 2-seriate; racemes usually straight .. .. *E. crus-galli* (L.) Beauv.
    - Spikelets awnless, 4-seriate; racemes upcurved .. .. *E. crus-galli* var. *frumentacea* W. F. Wight
  - Inflorescence ± nodding, the spikelets partly hidden by awns 10-25 mm. long; leaf-sheaths puberulous on the collar .. .. *E. walteri* (Pursh) Heller

Panicum fulgidum Hughes in Kew Bull. **1923**: 323 (1923).

Panicum bicolor R.Br. Prodr. 191 (1810), non Moench. (1794).

Panicum bicoloratum S. T. Blake in Proc. Roy. Soc. Queensl. **59**: 158 (1948).

Panicum bicoloratum was proposed as a new name because the epithet chosen by Hughes when renaming *P. bicolor* R.Br. "had already been used by Stapf for another species of the genus." This, however, is incorrect; the name published by Stapf was *Panicum fulgens*, not *Panicum fulgidum*, and *Panicum bicoloratum* is therefore a superfluous name. Mr. C. E. Hubbard, of the Kew Herbarium, kindly drew my attention to the error.

Paspalidium Stapf in Prain Fl. Trop. Afr. **9**: 15 (1917), *in clavi*, et 582 (1920), *descr.*

The name *Paspalidium* was proposed for a group of species previously included in *Panicum* and still so treated by some American botanists. The genus has a fairly distinctive facies, and it resembles *Setaria* rather than *Panicum* in the structure of the spikelet and the sterile tip of the branches of the inflorescence. The genus is widely distributed over the warmer parts of the world and is particularly well-developed in Australia where at least 21 of the 30 or so known species have been found. An account of the Australian species is in preparation, but some new records and descriptions of new species are given here; for the latter, only the types and general range are cited.

Paspalidium flavidum (Retz.) A. Camus in Lecomte Fl. Gén. Indo-Chine **7**: 419 (1922).

Panicum flavidum Retz. Obs. **4**: 15 (1786).

Queensland.—Cook District: Mareeba, open sandy ground, 375 m., 18th June 1935, *Blake* 9469. North Kennedy District: Mt. Julian, *Michael* 1405. Port Curtis District: Rosedale, uncommon, *Dovey* G.30; Rosedale, only on creek flats, 21st Jan. 1934, *Dovey* 459. Wide Bay District: Fraser Island, between Ungowa and the Forestry Station, in mixed forest on sand, 26th August 1941, *Blake* 14397; Fraser Island, Oct. 1921, *White*; Noosa, on sandy track through open forest above the beach, 15th July 1943, *D. A. & L. S. Smith*. Moreton District: Coolum, hillsides in open forest on sand, 15th April 1938, *Blake* 13747; Maroochydore, April 1916, *White*; Bribie Island, 10th April 1938, *White*; Stradbroke Island, March 1916, *Bick & White*; Enoggera Range, 1st May 1916, *White*; Sunnybank, Dec. 1916, *White*; Sunnybank, open forest on loose sandy soil, 7th Dec. 1933, *Blake* 4997; Sunnybank, 15th Feb. 1938, *L. S. Smith* 347; Brisbane, shady corner in University grounds, 28th April 1932, *Blake* 266; Canungra, on southern slopes of Mt. Tamborine, in *Eucalyptus* forest, 240 m. and upwards, 26th March 1937, *Blake* 12874.

New South Wales.—North Coast: Between Kingscliff and Norries Head, among *Imperata* and *Pteridium* in mixed open forest on slopes of low sandridges behind the coast, 19th April 1950, *Blake* 18495.

New for Australia, as all previous records from here appear to be based on misidentifications. It was definitely recognised by C. E. Hubbard when he sorted the material in the Queensland Herbarium in 1930-1. The Australian material agrees well with the type collected in Ceylon by Koenig (LD), but has somewhat longer leaves; the length of the spikelets varies from 2·6 to 3 mm. (2·6-2·9 mm. on the type), which is somewhat greater than the length given in most published descriptions of the species. Perhaps other species have been confused with it in Ceylon and India as in Australia. The following names and references must be considered in explaining the confusion with other Australian species:—

Panicum brizoides L.; F. Muell. Fragm. **8**: 189 (1874).

Panicum distans Trin. Spec. Gram. *t.* 172 (1829); non Willd. ex Spreng. Syst. Veg. **1**: 305 (1805), *pro syn.*

Panicum flavidum Retz. Obs. **4**: 15 (1786); R.Br. Prodr. 190 (1810); Benth. Fl. Austral. **7**: 474 (1878); Domin in Biblioth. Bot. **85**: 300 (1915).

Panicum flavidum Retz. var. *jubiflorum* (Trin.) Domin in Biblioth. Bot. **85**: 300 (1915).

Panicum flavidum Retz. var. *orarium* Domin in Biblioth. Bot. **85**: 300 (1915).

Panicum flavidum Retz. var. *tenuius* Benth. Fl. Austral. **7**: 474 (1878) ("*tenuior*"); Domin in Biblioth. Bot. **85**: 300 (1915).

Panicum globoideum Domin in Fedde Repert. Nov. Sp. **10**: 119 (1911).

Panicum gracile R.Br. Prodr. 190 (1810); Benth. Fl. Austral. **7**: 475 (1878).

Panicum jubiflorum Trin. Gram. Panic. Dissert. **2**: 150 (1826).

Panicum paractaenum Kunth Enum. **1** : 134 (1833).

Panicum retiglume Domin in Fedde Repert. Nov. Sp. **10** : 119 (1911).

Paractaenum novae-hollandiae Beauv. Agrost. 47, *t.* 10, *f.* 6 (1812) ; Hughes in Kew Bull. **1923** : 287-9 (1923).

Paspalidum distans (Trin.) Hughes in Kew Bull. **1923** : 317 (1923).

Paspalidium flavidum (Retz.) A. Camus in Lecomte Fl. Gén. Indo-Chine **7**: 419 (1922).

Paspalidium globoideum (Domin) Hughes in Kew Bull. **1923** : 317 (1923).

Paspalidium gracile (R.Br.) Hughes in Kew Bull. **1923** : 318 (1923).

Paspalidium jubiflorum (Trin.) Hughes in Kew Bull. **1923** : 317 (1923).

Paspalidium retiglume (Domin) Hughes in Kew Bull. **1923** : 317 (1923).

The first reference to the occurrence of *Paspalidium flavidum* in Australia was made by R. Brown (*Panicum flavidum*) ; he indicated that he saw living plants on the tropical coast, but I have seen no further reference to these specimens, unless they are the ones referred to *Paspalidium jubiflorum* by Hughes. F. Mueller treated *Panicum flavidum*, *P. distans*, *P. jubiflorum* and *P. paractaenum* as synonyms of *P. brizoides* L. which appears to be truly a synonym of *Echinochloa colonum* (L.) Link, but which has been misapplied to *P. flavidum.* Bentham cited four Australian collections under *Panicum flavidum* ; of these: one (Upper Victoria R., *Mueller*) became the type of *Panicum retiglume*, two (Peak Downs, *Burkitt*, and Springsure, *Wuth*) became syntypes of *P. globoideum*, while the fourth also appears to belong to *P. globoideum* (to judge from later references). *Panicum flavidum* var. *tenuius* was based on several specimens, some of which were later distributed by Hughes between *Paspalidium jubiflorum* and *Paspalidium distans.* Bentham also treated *Panicum jubiflorum*, *P. distans* and *Paractaenum novae-hollandiae* as synonyms of *P. gracile.* Domin (1915) referred only one collection to *P. flavidum*, his own from Winton, but from geographical considerations it must belong to *P. jubiflorum.* Under *Panicum flavidum* var. *jubiflorum* he synonymised *Panicum jubiflorum* and *P. distans*, but the only specimen cited came from a wet coastal locality and cannot be *P. jubiflorum* which belongs to the drier inland regions. From the notes given, *P. flavidum* var. *orarium* appears to be *P. distans.*

Paractaenum novae-hollandiae (*Panicum paractaenum*) is generically distinct from *Paspalidium* (Hughes, 1923). The species confused with *Paspalidium flavidum* may be distinguished by the following key:—

Rhachis of racemes articulate with the main axis, the racemes falling entire	*Paractaenum novae-hollandiae*
Rhachis of racemes not articulated with the main axis, long persistent ; spikelets falling separately and singly (*Paspalidium*) :	
Upper glume 9-13-nerved with the nerves anastomosing by means of cross-veins, at least in the upper part :	
Spikelets 2-2·7 mm. wide ; nerves anastomosing only in the upper part ; densely tufted perennial	*P. globoideum*
Spikelets 1·4-1·5 mm. wide ; nerves anastomosing almost throughout ; annual	*P. retiglume*

- Upper glume 5-7 (rarely 9) -nerved ; nerves free or uniting at or very close to the tip :
  - All or nearly all the racemes with the spikelets closely and evenly biseriate on pedicels 0·2-0·5 mm. long, those of each series more or less contiguous ; racemes nearly always simple :
    - Spikelets about twice as long as wide ; all or nearly all the racemes longer than the internodes of the main axis ; leaf-sheaths glabrous throughout . . . . . . *P. jubiflorum*
    - Spikelets about 1·5-1·7 times as long as wide ; lower racemes much shorter than the internodes of the main axis ; leaf-sheaths more or less ciliate on at least one margin, particularly near the top :
      - Spikelets 2·6-3 mm. long, 1·4-1·6 mm. wide, widely spreading from the rhachis, those of each series contiguous for about half their length, not strongly curved in profile . . *P. flavidum*
      - Spikelets 2-2·5 mm. long, 1·1-1·25 mm. wide, obliquely spreading, those of each series contiguous only by the base of the one above and the tip of the one below . . . . . . *P. distans*
  - Racemes with the spikelets loosely arranged or irregularly biseriate, slightly contiguous to distant on pedicels 0·25-5 mm. long ; at least the lower racemes with 1 or more 1-flowered branches . . . . *P. gracile*

Paspalidium basicladum Hughes in Kew Bull. **1923** : 318 (1923).

Queensland.—Burke District : Cloncurry, on stony to rocky quartzite hillsides about 225 m., 7th Nov. 1935, *Blake* 10123. Gregory North District : Tranby, 22° 40′ S., 142° 25′ E., gullies in rugged sandstone ridges, 165-210 m., with *Triodia* sp., 8th May 1936, *Blake* 11410, 11411 ; Elderslie, W. of Winton, garden weed, one specimen seen, 27th Oct. 1935, *Blake* 10006.

South Australia.—Flinders Ranges : Near Blinman, on barren stony slopes in mixed low scrub, 420-450 m., 31st August 1946, *Blake* 16904.

New for both Queensland and South Australia.

Paspalidium clementii (Domin) C. E. Hubbard in Kew Bull. **1934** : 447 (1934).

Panicum clementii Domin in J. Linn. Soc. Bot. **41** : 272 (1912).

Queensland.—Gregory North District : Duchess, in rock crevice on low rugged hill, about 390 m., 18th May 1936, *Blake* 11531 ; near Boulia, on low stony ridge with scattered *Acacia* spp., etc., 24th July 1936, *Blake* 12379 ; Tranby, 22° 40′ S., 142° 25′ E., gullies in rugged sandstone ridges, 165-210 m., with *Triodia* sp., 8th May 1936, *Blake* 11412 ; Elderslie, W. of Winton, on stony hillside, 5th June 1936, *Blake* 11657. Gregory South District : Betoota, on barren stony desert hills, 17th July 1936, *Blake* 12177 ; 45 miles W. of Windorah, on scrubby, stony, sandstone ridges, about 150 m., 14th July 1936, *Blake* 12125 ; Mt. Howitt Station, about

70 miles W. of Eromanga, on barren sandstone hillsides under *Acacia* spp., 180-240 m., 3rd July 1936, *Blake* 11917. North Kennedy District: Charters Towers, sandstone ridge, *Eucalyptus-Acacia* forest, 330-360 m., 11th June 1936, *Blake* 11705.

New for Queensland.

P. basicladum and *P. clementii* were hitherto known only from Western Australia, the former from the south, the latter from the north. The specimens cited constitute a wide extension of range for both species, and it is interesting to note that the ranges of the two overlap in western Queensland, both having been collected together at Tranby and in different years at Elderslie. They are closely allied annual species which may be distinguished as follows :—

Spikelets 2·75-3·1 mm. long, elliptic-oblong, ± acute ; upper floret distinctly attenuated towards the base, coarsely though shallowly rugose ; culms ± scabrous ; lower racemes mostly overlapping	*P. basicladum*
Spikelets 2-2·4 mm. long, oblong to somewhat elliptic, ± obtuse ; upper floret scarcely attentuated towards the base, faintly and finely rugose ; culms smooth ; lower racemes ± distant ..	*P. clementii*

Two other annual species are known. *P. tabulatum* (Hack.) C. E. Hubbard is distinguished by its filiform leaves and *P. rarum* (R.Br.) Hughes by all the racemes reduced to 2 or (more usually) 1 spikelet.

Paspalidium albovillosum S. T. Blake ; species nova affinis *P. distanti* (Trin.) Hughes et *P. caespitoso* C. E. Hubbard ; ab hoc foliis latioribus ab illo spiculis haud incurvis, ab utroque spiculis paullo minoribus latioribusque atque foliis et inflorescentiae axi ramisque pilis longis mollibus vestitis differt.

Gramen perenne, pallide virens vel flavovirens. Culmi caespitosi, recti, usque ad 40 cm. longi, graciles, molles, laeves, 3-5-nodes, ramosi, prope inflorescentiam saepe laxe pilosi ceterum glabri. Folia pilis longis gracilibus mollibus albis e tuberculis ortis dense hirsuta ; vaginae plus minusve carinatae, arcte convolutae vel hiantes, tenues, conspicue nervosae, margine altero longe ciliatae, dorso sursum hirsutae, nodis glabrae, inferiores internodiis longiores, superiores breviores ; ligulae ad marginem augustissimum breviter ciliatum redactae, in toto circa 0·5 mm. longae ; laminae molles, anguste lineares, breviter acutae, planae vel plus minusve incurvae, explanatae 1–4 mm. latae, usque ad 15 cm. longae, utrinque molliter hirsutae, sursum marginibus scabridae. Inflorescentia longe exserta, 8–15 cm. longa ; axis communis plus minusve triquetra, pro majore parte vel omnino longe laxeque pilosa (pilis tenuibus mollibus e tuberculis ortis), sursum angulis minute scabrida. Racemi 6–10, inferiores plerumque 1–2 cm. longi, internodiis axeos communis breviores, interdum prope basim ramosi, superiores gradatim breviores internodiis paullo longiores, simplices ; rhachis flexuosa, circa 0·25 mm. lata, triquetra, marginibus longe ciliata, seta 0·5–2 mm. longa terminata ; pedicelli 0·2–2·4 mm. longi, pilosi, apice discoidei, inter se 0·25–1·5 mm. distantes. Spiculae purpurascentes, biseriatae, contiguae, oblique patentes, ambitu ellipticae vel ovato-ellipticae vel obovato-ellipticae, late acutae, prope basim admodum attenuatae, facie depressae a latere visae rectae (haud incurvae), dorso alte convexae, 1·5–1·9 mm. longae, 1–1·2 mm. latae, glabrae. Glumae membranaceae, tenuiter nervosae ; inferior dimidiam spiculam aequans vel fere aequans et ejus basim amplectens, oblata, late obtusa, 3-nervis nervis lateralibus cum medio prope apicem conjunctis; superior tres usque novem partes spiculae attingens, late rotundata, 5–7-nervis nervis subparallelis fere percurrentibus. Anthoecium inferum sterile: lemma spiculam aequans, explanata late rotundata, 5-nervis; palea usque circa 0·6 mm. longa vel 0. Anthoecium superum spiculae apicem attingens, fere ellipticum, utrinque acutum, apice subacuminatum brevissime apiculatum (apiculo fere recto), dorso leviter reticulatum minime rugulosum.

Typus: Queensland; Maranoa District, 20 miles W. of Mitchell, dense *Cadellia–Acacia* forest, greyish gravelly silt loam, 480 m., 31st March 1936, *Blake* 10947.

The species is represented by 23 collections from Queensland collected in the Districts of South Kennedy, Wide Bay, Burnett, Leichhardt, Warrego, Maranoa, Darling Downs and Moreton. It is easily recognised by the small but broad spikelets and the long, slender, soft, more or less spreading hairs on the leaf-blades, main axis of the inflorescence, rhachis of the racemes and the pedicels.

Paspalidium spartellum S. T. Blake; species nova, affinis *P. gracili* (R.Br.) Hughes, sed foliorum vaginis (haud carinatis) laminisque brevibus, racemis omnibus 1-2-spiculatis, pedicellis perbrevibus, anthoecio supero basim versus rotundato apice recto dorso vix ruguloso differt.

Gramen perenne, caespites duros efformans. Culmi erecti, circa 50 cm. alti, graciles, duri, rigidi, teretes, striolati, laeves, glabri, 5–8-nodes, iterum ramosi ramis ramulisque patulis. Folia brevia; vaginae primum convolutae teretes, demum solutae et apertae, haud carinatae, conspicue nervosae, internodiis multo breviores, glabri laevesque; ligulae ad marginem brevissime ciliolatum in toto circa 0·15 mm. altum redactae; laminae patulae vel deflexae, angustissime lineares, acutissimae, rigidae, involutae, explanatae usque ad 1 mm. latae, nervis utrinque scabridae ceterum glabrae laevesque, usque ad 6 cm. longae. Inflorescentia exserta, pauciflora, subracemiformis, 1·5–3·5 cm. longa; axis communis inferne compresso-canaliculata sursum subtriquetra, omnino scabrida. Racemi 4–6, erecti, ad spiculas 1–2 redacti, inferiores distantes saepe ramosi, superiores contigui simplices; rhachis triquetra, scabrida, circa 0·25 mm. lata, seta subulata 0·5–1·5 mm. longa terminata; pedicelli 0·4–0·6 mm. longi, scabridi, apice discoidei, usque 1·5 mm. distantes. Spiculae brunnescentes, erecti, ambitu angustius ellipticae acutae, prope basim constrictae, a latere visae rectae, 2·9–3 mm. longae, 1·1–1·2 mm. latae, conspicue nervosae. Glumae membranaceae; inferior ovata, acuta, duas partes spiculae aequans vel fere aequans, valide 3-nervis nervis prope apicem convergentibus; superior quattuor partes spiculae aequans, specie acuta sed explanata rotundata, 5-7-nervis, nervis 5 prope apicem convergentibus et ibi cum se unitis ceteris brevibus. Anthoecium inferum sterile; lemma glumae superiori simile sed spicula aequilongum, 7-nerve nervis prope apicem convergentibus cum se conjunctis; palea 0. Anthoecium superum spicula aequilongum, oblongo-ellipticum, acutum, minute apiculatum, plano-convexum, tenuiter reticulatum, dorso inferiore inconspicue tenuissimeque rugulosum.

Typus: Queensland; North Kennedy District, W. of Pentland, between Warrigal and Burra, on slopes of Great Dividing Range, in open forest on shallow sand overlying sandstone, 450–495 m., 19th October 1935, *Blake* 9939.

Known only from the type-collection, this species is very distinct in appearance by reason of the wiry branched culms, short and often deflexed leaves with short spreading sheaths which at length open out to become nearly flat, and short, reduced inflorescences of few racemes with only 1–2 strongly nerved spikelets.

Paspalidium criniforme S. T. Blake; species nova, affinis *P. gracili* (R.Br.) Hughes, sed spiculis paullo minoribus pro rata angustioribus, anthoecio supero brevissime apiculato basi vix attenuato praecipue differt.

Gramen perenne viride. Culmi caespitosi, erecti vel geniculati, circa 10–27 cm. alti, setacei, compressi, striolati, glabri, laeves, 4–7-nodes, iterum ramosi. Folia pilis longiusculis tenuibus e tuberculis parvis ortis praedita; vaginae carinatae, crebre nervosae, laeves, sursum laxe pilosae, ore barbatae, vel omnino glabrescentes, primo convolutae tandem per ramos solutae, inferiores internodiis longiores, superiores eis breviores; ligulae ad seriem ciliorum vix 0·2 mm. longorum redactae; laminae plerumque setaceo-involutae, raro planae et usque 1·5 mm. latae, usque 6·5 cm. longae, utrinque pilosae, supra nervis marginibusque scabridulae. Inflorescentia fere filiformis, pauciflora, 2·5–6 cm. longa vel interdum brevior; axis communis canaliculato-triquetra, sursum minute scabrida. Racemi 4–6, appressi, inferiores usque 1 cm. longi, saepe ramosi, usque 5 spiculas gerentes, superiores breviores, his vel interdum omnes unispiculati; rhachis anguloso-filiformis, circa 0·15 mm. lata, scabrida, leviter flexuosa, seta 2–4 mm. longa terminata; pedicelli 1–2 mm. longi, scabriduli, apice discoidei. Spiculae quasi uniseriatae, pallidae, suberectae glabrae, ambitu elliptico-lanceolatae vel oblongo-lanceolatae, acutae, acuminato-apiculatae, plano-convexae haud incurvae, 2–2·2 mm. longae, 0·9–1 mm. latae, nervis angustis viridibus conspicue notatae. Glumae membranaceae; inferior ovata, acuta, spiculae duas partes aequans vel fere aequans, 3- vel sub-5-nervis; superior elliptica, late rotundata, spiculae tres usque quinque partes aequans, 5- vel sub-7-nervis nervo mediano percurrenti lateralibus prope apicem incurvis cum se junctis, eis paris tertii brevibus saepe liberis. Anthoecium inferum sterile: lemma spiculam aequans, specie apiculatum sed explanatum ellipticum rotundato-obtusum, 5-nerve, utrinsecus nervum medianum sulcatum; palea minuta. Anthoecium superum ovatum, acutum, minute apiculatum (apiculo incurvo), dorso alte convexo rugulosum.

TYPUS: Queensland; Moreton District, Moggill near Brisbane, on dry hillside in mixed open forest, 10th March 1934, *Blake* 5282.

The species is known from five collections from the Moreton District of Queensland. The dense tufts of very slender culms and very fine leaves and the very slender inflorescences of few, small spikelets give the plant a distinctive appearance. The living plants have a faint but distinct curry-like odour.

Paspalidium udum S. T. Blake; species nova, affinis *P. punctato* (Burm.) A. Camus (speciei asiaticae), *P. paludivago* (Hitchc. & Chase) Parodi (speciei americanae) et *P. geminato* (Forsk.) Stapf (speciei fere cosmotropicae), sed spiculis majoribus, gluma superiore manifeste 5-nervi, anthoecio supero manifeste ruguloso ab omnibus differt.

Gramen perenne, viride. Culmi elongati, usque metrales, basi plus minusve repentes et nodis inferioribus radicantes, sursum adscendentes, molles, striati, laeves, glabri, multinodes, ramosi, inferne usque 7 mm. crassi. Folia plus minusve conferta; vaginae primo convolutae mox hiantes, parte superiore carinatae, glabrae laevesque, internodiis plerumque longiores; ligulae ad marginem longe ciliatum redactae, in toto circa 1·5 mm. longae; laminae anguste lineares, acutae, basim versus leviter angustatae, planae vel saepius convolutae vel involutae, marginibus atque nervis supra scabridae ceterum glabrae laevesque, quoad magnitudo maxime variabiles, saepius 4–8 mm. latae et 5–20 cm. longae. Inflorescentia angustissima, tandem exserta, 14–22 cm. longa; axis communis inferne compressa canaliculata laevis, sursum triquetra admodum scabrida. Racemi 10–16, appressi, inferiores distantes, superiores vel plures imbricati, omnes simplices, plerumque 1·5–3 cm. longi, supremi plerumque breviores; rhachis leviter anfractuosa, triquetra, scabro-ciliata, circa 0·6–0·7 mm. lata, seta subulata 1–4 mm. longa terminata; pedicelli cuneati, scabri, 0·2–0·3 mm. longi, apice plus minusve discoidei, circa 1–1·5 mm. distantes. Spiculae confertae, eleganter biseriatae, fere erectae, eae seriei cujusque longe imbricatae, manifestius nervosae, ambitu oblongo-ovatae vel oblongo-ellipticae, acutae, a latere visae rectae, facie leviter concavae, 3–3·3 mm. longae, 1·2–1·5 mm. latae. Glumae membranaceae; inferior quartam vel tertiam partem spiculae subaequans, oblata, truncata vel admodum rotundata, enervis; superior tres quintas vel tres quartas partes spiculae aequans, elliptica, rotundo-obtusa, conspicue 5-nervis nervo mediano percurrente ceteris subparallelis prope marginem incurvis conjunctisque vel nervo transverso irregulari inconspicuove unitis. Anthoecium inferum sterile: lemma membranaceum, spicula aequilongum, explanatum oblongo-ellipticum rotundo-obtusum, 5-nerve nervis sursum convergentibus et juxta marginem unitis mediano percurrenti; palea lemmate aequilonga, hyalino-membranacea, 2-carinata, marginibus late inflexa. Anthoecium superum spicula aequilongum vel fere aequilongum, ambitu ovatum acute acuminatum, apiculatum, a latere visum rectum, depresse plano-convexum, reticulatum et rugulosum; lemma tenuiter 5-nerve. Antherae 1·2 mm. longum.

TYPUS: Northern Territory; Near Alligator Point, Daly R., 13° 26′–29′ S., 130° 26′–27′ E., common in damp places with *Phyla nodiflora*, 15 m., 28th July 1946, *Blake* 16659.

Known only from the type-collection, this species differs in habit from other Australian species in the coarse, spongy, creeping and ascending culms in which it resembles *P. geminatum* (Forsk.) Stapf (a nearly cosmotropical species which is the type of the genus), *P. punctatum* (Burm.) A. Camus (from Asia) and *P. paludivagum* (Hitchc. & Chase) Parodi (from America). The first-mentioned differs from the others in its much smaller, rather broadly ovate spikelets with an almost quite smooth fertile floret; it was based on *Panicum geminatum* Forsk., the type of which is a specimen collected at Damietta, Egypt, by Forskahl (C). *P. punctatum*, *P. paludivagum* and *P. udum* are much alike in general appearance and characters of the spikelet, but there are minor differences in the size and shape of the spikelet, the relative length of the upper glume, the number and distinctness of the nerves of the upper glume and lower lemma, and in the surface of the fertile floret. *P. udum* has the largest spikelets with the most prominent nerves and distinctly rugulose fertile florets; its upper glume is 5-nerved and at least usually 3-nerved in the others.

The combination *Paspalidium paludivagum* has been made independently on three different occasions: Parodi Gram. Bonar. ed. 3, 85, 89 (1939); Henrard in Blumea **3** (**3**): 434 (1940); and Pilger in Engl. & Prantl Pflanzenfam. ed. 2, **14e**: 29 (1940).

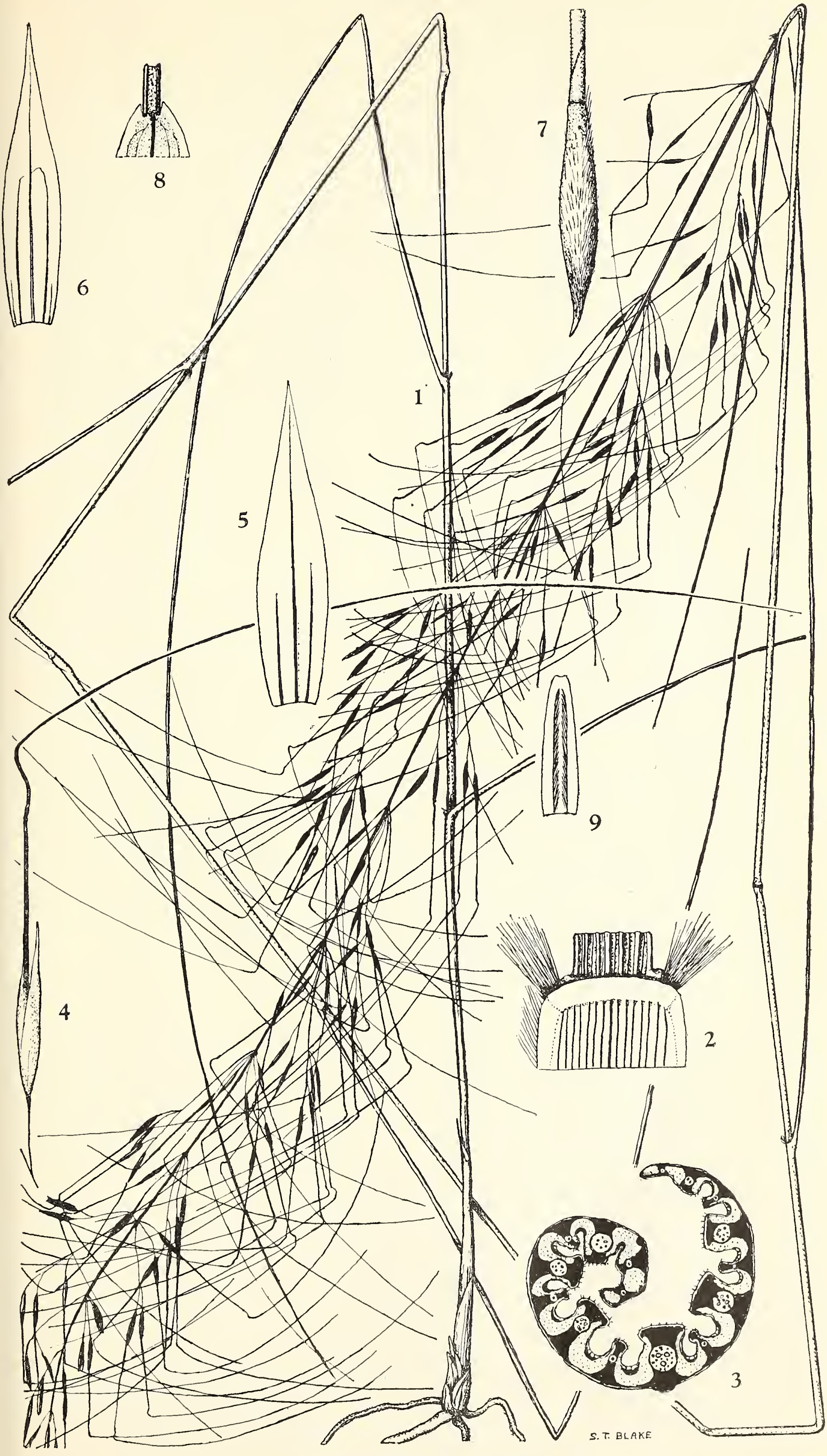
EXPLANATION OF PLATES.

Plate V.

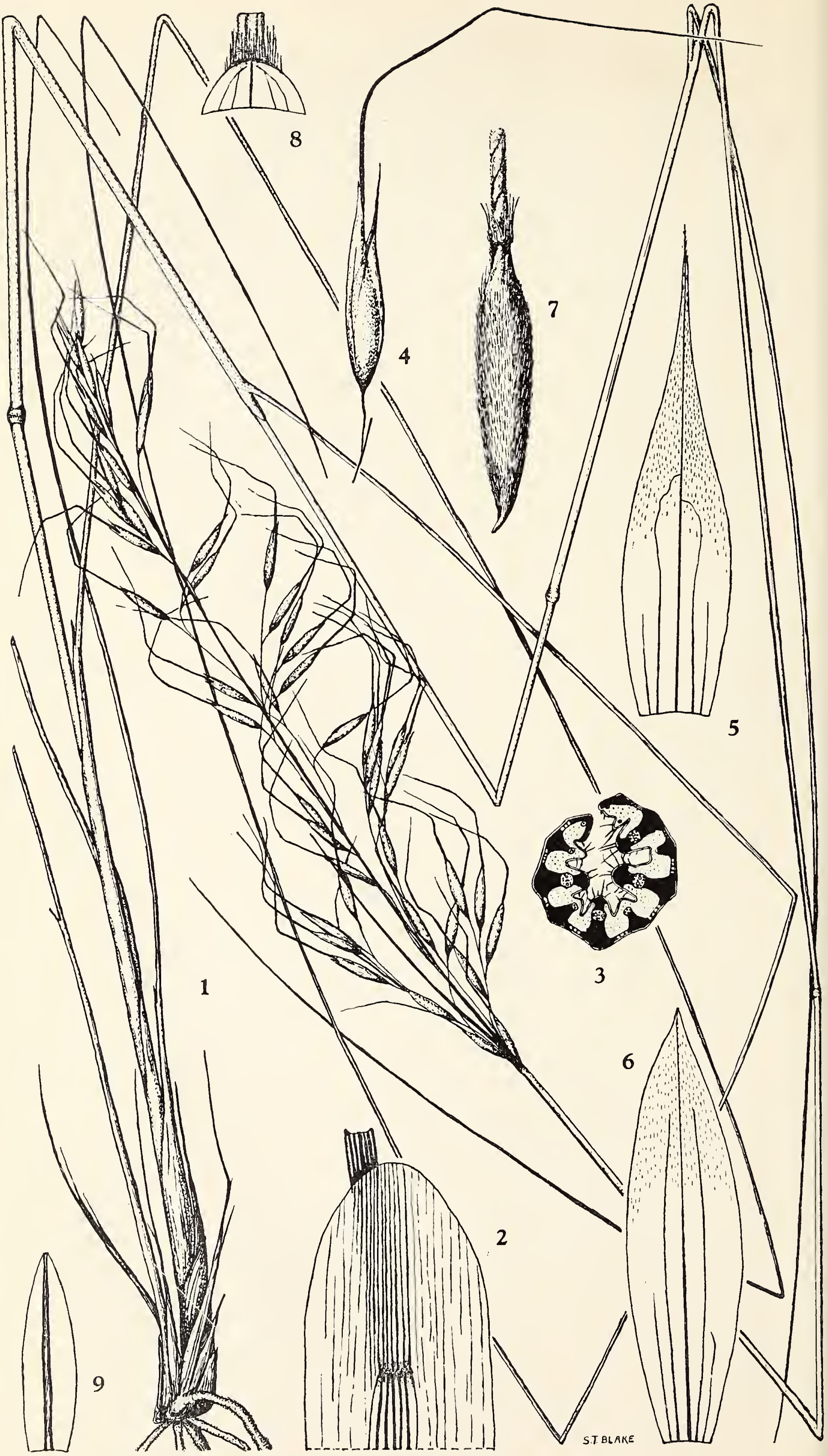
Stipa nodosa S. T. Blake. Fig. 1, portion of plant, natural size; 2, ligule, with part of sheath and blade, flattened out × 6; 3, transverse section of leaf, × 30; 4 spikelet, × 3; 5, lower glume, flattened out, × 6; 6, upper glume, flattened out, × 6; 7, floret, greater part of awn removed, × 6; 8, part of lemma with base of awn, flattened out, × 6; 9, palea, flattened out, × 6.—From type.

Plate VI.

Stipa brachystephana S. T. Blake. Fig. 1, portion of plant, natural size; 2, ligule with part of sheath and blade flattened out, × 6; 3, transverse section of leaf × 30; 4, spikelet, × 3; 5, lower glume, flattened out, × 6; 6, upper glume flattened out, × 6; 7, floret, greater part of awn removed, × 6; 8, tip of lemma with base of awn, flattened out, × 6; 9, palea, flattened out, × 6.—From type.



Stipa nodosa S. T. Blake.



Stipa brachystephana S. T. Blake.

NOTES ON SOME AUSTRALIAN COMPOSITAE.

By J. H. Willis, National Herbarium of Victoria, Melbourne.

(With Plate VII and one Text-figure.)

(*Issued separately, 22nd August, 1952.*)

Summary.

Two new species of *Helichrysum* and one of *Chthonocephalus* are described from Queensland, New South Wales, and Western Australia respectively, and a necessary change made in the name of a species of *Erechthites*, now regarded as a *Senecio*. The distributions of four species of *Helichrysum* are mapped.

Helichrysum eriocephalum *J. H. Willis;* species nova ex affinitate *H. cordati* DC., *H. ramosi* DC. et *H. obovati* DC., a quibus differt foliis supra constanter arachnoideis, inflorescentiis multo minoribus (in specimine unico), involucri squamis longius lanigeris laminis albis latioribus plicatisque.

Suffrutex laxus, saltem 50 cm. altus, ramis gracilibus albido-tomentosis. *Folia* lanceolata brevissime petiolata, inferiora circiter 5 × 1 cm., summa minora, distantia, omnia utrinque arachnoideo-lanuginosa, marginibus revolutis, subtus nervo medio lateralibusque paucis prominentibus. *Inflorescentia* densissime lanuginosa terminalis restricta, corymbis confertis in panicula parva laxa dispositis. *Capitula* albida subsessilia subhemisphaerica, circa 5 mm. lata, usque 40-flora. *Involucri squamae* 30–40, circa 5-seriatae, spathulatae, superiores 2–3 mm. longae, stipite a lana occulto, solum lamina alba brevi (usque ad 1 mm. longa) lata obtusa subplicataque aperta; ob vestem arachnoideo-lanuginosam intricatam difficillime segregandae. *Flores* circa 3 mm. longi, corollae lobis 5 brevibus papulas sparsas ferentes. *Pappi setae* circa 20, circa 2·5 mm. longae, scabridae, corollam vix excedentes, ad apicem incrassatae, ad basin in corona (latiore quam ovario) connatae. *Achaenia* immatura breviter cylindrica glabra. *Styli ramuli* 0·5–1·0 mm. longi, ad apices brevissime denseque penicillati. *Antherae* circa 1·5 mm. longae, caudis brevibus paulum lobatis; filamentis gracilibus. Pollinis granula circa 18 mic. diam., regulariter echinulata.—Plate VII, figs. 1–7.

Queensland.—South Kennedy District: Lake Elphinstone, about 100 miles WSW of Mackay, 1870, *Amalie Dietrich* 1722 (holotype in mel; clastotype in bri.).

Notwithstanding the undesirable practice of describing new species from single herbarium specimens, I do not hesitate to publish a diagnosis of this hitherto undescribed plant which differs in so many ways from other species of *Helichrysum.* F. Mueller had long ago labelled the collection "*H. Beckleri* F.v.M. (var.)"; but it has conspicuous white and crinkled spreading tips to the involucral bracts, both surfaces of the rather large lax remote leaves persistently arachnoid-woolly, and bears very little resemblance to this shrub. In January 1947 the late Mr. C. T. White, to whom I submitted this puzzling Queensland plant for examination, reported that he had seen nothing like it and suggested my describing it as new.

With, apparently, a weak and straggling habit, its white-woolly branches, moderately large, broad leaves and exceedingly woolly heads (the bracts difficult to disentangle), *H. eriocephalum* is obviously allied to *H. cordatum, H. ramosum* and *H. obovatum*—all Candollean species in the Section *Ozothamnus*. *H. obovatum* of north-eastern New South Wales differs in having glabrescent leaves on slender petioles and very minute, non-spreading tips to the involucral bracts. The other two species are Western Australian and differ in their large, diffuse, leafless panicles, the bracts much less hairy with narrower white tips (never crinkled as in the new species), and the more sharply scabrid pappus bristles which are not fused at the base to form a broad crown. It would be most interesting to ascertain whether the plant still survives in the neighbourhood of Lake Elphinstone and what is the nature of its habitat.

Helichrysum tuckeri F. Muell. ex *J. H. Willis;* species nova, de forma foliorum solummodo *H. diotophyllo* F. Muell. comparabilis, cujus autem folia basi amplius auriculata, sursum angustiora et marginibus paulo distantibus subtus tomentosa, capitula ampliora flores usque 40 tenentia, involucrum nitenti-flavescens, pappi setae minus incrassatae et achaenia fere sericata sunt; *H. diosmifolium* (Vent.) Sweet, quod forma et colore capitulorum speciei novae simillimum, foliis multo longioribus anguste linearibus patentioribus, floribus in capitulo pluribus differt.

Frutex rigidus, 60–120 cm. altus, ramis numerosis virgatis gracilibus tenuissime tomentellis. *Folia* glabra angusto-oblonga, obtusa sessilia perbrevia (circiter 3–4 × 1 mm.), ad basin latiora et brevissime biloba, erecta appressa conferta, subtus sulco angustissimo percursa, marginibus replicatis paginam inferam plane occultantibus. *Inflorescentia* terminalis, paniculata, fere globularis, 1–3 cm. lata, ex corymbis capitulorum constructa. *Capitula* albida, haud nitentia, breviter pedunculata, primum pilularia demum campanulata, 3–4 mm. lata, 7–12-flora. *Involucri squamae* 30–40, circa 5-seriatae, integrae, glabrae vel ad stipitem parcissime lanuginosae; superiores obovato-oblongae, circa 3 mm. longae, sursum albae, inferne secus stipitem hyalinae; inferiores minores ad formam orbicularem vergentes. *Flores* circa 2·5 mm. longi, sub anthesi involucrum parum superantes, corollae lobis 5 minutissime papulatis. *Pappi setae* corollam aequantes haud numerosae, 1·5–2 mm. longae, minute scabridae, apicem versus leniter incrassatae, ad basin fere liberae. *Achaenia* circa 0·5 mm. longa, breviter cylindrica, dense papilloso scabriuscula. *Styli ramuli* circa 0·6 mm. longi, ad apices brevissime denseque penicillati. *Antherae* circa 1 mm. longae, caudis brevibus acuminatis; filamentis gracilibus. Pollinis granula circa 18 mic. diam., sparsim echinulata.—Plate VII, figs. 14–20.

NEW SOUTH WALES.—Western Plains: Lake Cargelligo, Nov., 1915, *J. W. Dwyer;* "Lachlan River," 1879, *Gerard Tucker* (HOLOTYPE in MEL, CLASTOTYPE in NSW); Shuttleton Dec. 1903, *W. Bäuerlen;* Lachlan to Darling River, *G. Day;* Nyngan, Dec. 1899, *W. Bäuerlen;* Girilambone, Nov., 1890, *E. Betche;* Pilliga-Gwabegar, Dec., 1932 *H. M. R. Rupp.* Central Western Slopes: Kamarah via Barellan, 17th Oct., 1917, *W. R. A. Baker;* Ardlethan, Nov., 1917, *J. L. Boorman;* Weddin, Dec. 1899, *J. H. Maiden;* Wyalong, Oct., 1903, *J. L. Boorman;* Wyalong to Barmedman, Mar., 1915, *J. W. Dwyer;* Temora, Oct., 1915, *J. W. Dwyer;* Dudauman, 10 miles NW. of Cootamundra, Nov., 1917, *J. L. Boorman.* Southern Western Slopes: Near Wagga Wagga (? collector).

? VICTORIA.—"Wimmera," 1894, *W. H. Matthews.*

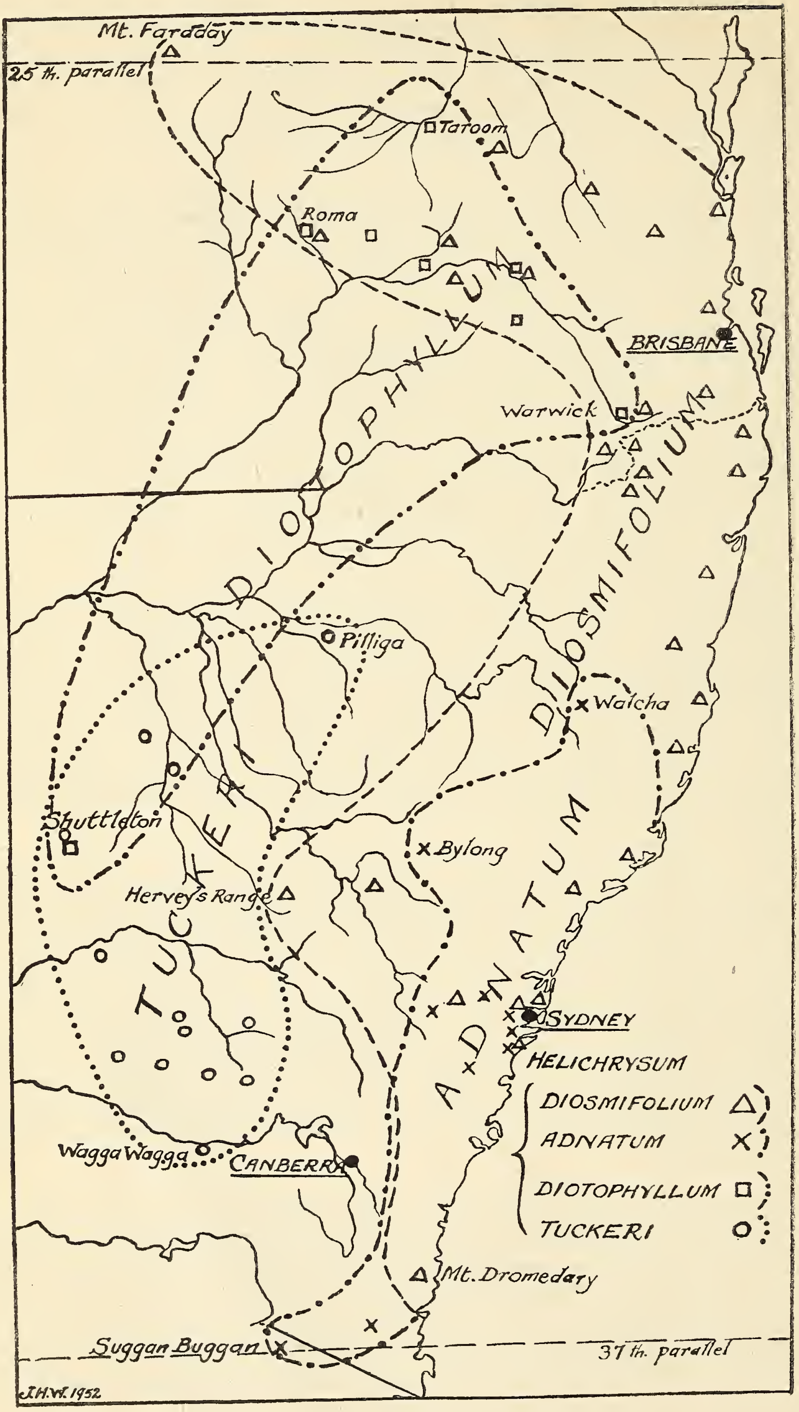
[All collections available in the National Herbaria at Melbourne, Sydney and Brisbane are cited here.]

Adopting a manuscript epithet given in 1879 by F. Mueller, who was the first to recognize the specific distinctiveness of *H. tuckeri,* I have drawn freely from his detailed notes accompanying the type specimen in the Melbourne Herbarium. Apparently it had been Mueller's intention to publish this name, honouring the original collector, and his epithet is now perpetuated as a mark of respect.

This rigid shrub (to four feet high) has hitherto been confused with *H. diotophyllum* F. Muell. which has rather similar appressed foliage and shares the northern part of its range on the Western Plains of New South Wales. Leaves of the new species are almost intermediate between those of *H. diotophyllum* (with large basal auricles) and the non-auriculate *H. adnatum* (DC.) Benth.; but its white, pilular flower-heads in small, globoid panicles are quite dissimilar, more closely approaching those of the much larger-leaved *H. diosmifolium* (Vent.) Sweet. All four species occur in New South Wales and are confined to eastern Australia, between the 25th and 37th parallels of south latitude (as far as existing records show). *H. diosmifolium* has by far the longest range, extending from Mt. Faraday (NE. corner of Warrego District) and Laguna Bay in Queensland to Hervey's Range near Peak Hill and Mt. Dromedary on the SE. coast of New South Wales; it is predominantly a plant of better-watered, hilly country, and in the southern area of distribution mingles with *H. adnatum* (from Walcha on and east of the Dividing Range to Suggan Buggan in far eastern Victoria where several other tableland species reach their southern limit). *H. diotophyllum* is co-extensive with *H. diosmifolium* in the Darling Downs District—the only two members of this group in Queensland—while in western New South Wales (as at Shuttleton) it accompanies *H. tuckeri* which ranges from Pilliga southward to Wagga Wagga, with a strong development in the Wyalong-Temora district.

A collection of *H. tuckeri* in the Melbourne Herbarium labelled "Wimmera" (from W. H. Matthews at Stawell Technical College, 1894) is of doubtful origin. It was exhibited by Mueller as new for Victoria at the meeting of the Victorian Field Naturalists' Club in March, 1894, and is the basis of the record of *H. diotophyllum* in Victoria by Ewart (1930). No other specimen of the species is known from this State and it is highly probable that Matthews either collected his material during a visit to New South Wales or received it through some correspondent there—certainly Stawell is far beyond the expected dryland habitat of *H. tuckeri,* not to mention the still more northerly *H. diotophyllum.*

The known distribution of these four species is shown in text-fig. 1, and the differences between their leaves in pl. VII, figs. 20–24. Maiden and Baker (1895) described two other species in this group, viz., *H. tesselatum* and *H. brevidecurrens*—both from Murrumbo on the upper Goulburn River, New South Wales. I have seen type materials and, although their leaves are much longer and less appressed (fig. 23) than in typical *H. adnatum* (fig. 22), with the heads considerably larger (*H. tesselatum* also has more coarsely papillate achenes), the differences from this species and one another do not seem to be specific. Further investigation in the field may show that these are connected with a variable *H. adnatum* by a series of intermediate forms.



Text Fig 1.—Distribution maps for *Helichrysum diosmifolium* (Vent.) Sweet, *H. adnatum* (DC.) Benth., *H. diotophyllum* F. Muell. and *H. tuckeri* sp. nov. — from material in Melbourne, Sydney and Brisbane Herbaria.

Chthonocephalus multiceps *J. H. Willis;* species nova ob capita composita numerosa dissita a tribus aliis speciebus *Chthonocephali* valde distincta; *C. tomentellus* (F. Muell.) Benth. habitu staturaque simillimus est, sed capitibus terminalibus solitariis, floribus pluribus et pappo nullo differt.

Herba annua rosulata pluricaulis. Caules nigri, subfiliformes, radiantes, subprostrati, usque ad 7 cm. longi, fragmenta tomenti arachnoidei ferentes. *Folia* caulis extremitatem versus decrescentia; inferiora atque vetustiora usque ad 2·5 cm. longa, oblanceolata, subglabrescentia; superiora conferta, 3–5 mm. longa, obovata, valde lanigera pilis adpressis intricatis basi inflatis 30 mic. latis, apice longe flagellatis. *Capita composita* inflorescentiae usque 40 per plantam, axillaria atque terminalia, subdissita, sessilia, pallide flavescentia, modice lanuginosa; summa maxima, congesta, pulviniformia, 5–12 mm. diam. *Capitula* usque 40 in capitibus majoribus, 3–6 flora, receptaculo spiculam brevissimam formanti. *Involucri squamae* usque ad 3 mm. longae, dimorphae; paucae bracteae exteriores stipite angusto, praeter basin laciniatae atque intricate lanuginosae; bracteae interiores 4–7, obovatae glabrae, hyalinae, manifeste areolatae, marginibus subintegrae. *Flores* 2–2·5 mm. longi, quisque ad basin a bractea lanata partim clausus (bracteae subtendentes involucri squamis exterioribus simillimae); corolla anguste infundibuliformis, lobis 5 conspicuis omnino glabris. *Pappi squamae* 5–7, quam corolla circiter triplo breviores, ad basin connatae, laciniatae, supra pilis intricatis ornatae, in floribus summis breviores, paucilobati, glabri. *Achaenia* triquetra, obovoideo-turbinata stylo-basi persistenti, 0·5–0·8 mm. longa, nubila, omnino minute papillosa. *Styli ramuli* 0·5–1 mm. longi, ad apicem penicillati papillis longis radiantibus. *Antherae* 1–1·5 mm. longae apiculis sterilibus conspicuis, caudis longis gracilibus; filamenta perbrevia, prope medium corollae tubum affixa. Pollinis granula 18–20 mic. diam., acriter echinulata.—Plate VII, figs. 25–33.

WESTERN AUSTRALIA.—South-East Division (Euclonia): Balladonia Homestead, 128 miles east of Norseman, on sandy soil against large granite slabs, with ephemeral *Helipterum* spp., etc., 31st August, 1947, *J. H. Willis*, Grimwade Expedition (HOLOTYPE in MEL, PARATYPE in PERTH, CLASTOTYPE in BRI.).

Both the author and Mr. C. A. Gardner, who examined the material 24/3/1948, at first considered this remarkable plant to be a species of *Gnephosis* which it resembles outwardly; but the presence of subtending scales between the florets shows its affinity with *Craspedia* and *Chthonocephalus* in the sub-tribe *Angiantheae.* Members of the former genus have long, erect peduncles, a general involucre, long, plumose pappus scales, and a silky-hairy achene. The newly described plant lacks these features, and conforms well to the present circumscription of *Chthonocephalus,* making a fourth species in that genus. In its growth form *C. multiceps* approximates to the west-coast (Western Australia) species *C. tomentellus,* but in this the inflorescences are wholly terminal on the woolly branches and the numerous florets are completely devoid of any pappus. The only other species with a pappus is *C. pygmaeus*—a rare, minute, stemless plant with narrowly linear leaves—which could never be mistaken for the new one. *C. multiceps* is at once recognizable by its very numerous compound heads (to 40) of varying sizes, and it is only to be expected that it will prove to have a wide distribution in the botanically little-known south-eastern part of Western Australia.

Senecio runcinifolius *J. H. Willis,* nomen novum.

Erechthites picridioides Sonder & F. Muell. in Linnaea **25**: 523 (1852), non *E. picridioides* Turczaninow, 1851.

E. mixta sensu Benthami in Fl. Aust. **3**: 659 (1866), non (A. Rich.) DC., 1837.

South Australia.—Murray River at Moorundee near Blanchetown, Feb. 1851, F. Mueller (holotype & paratypes in mel); "Towards Spencer Gulf", *Warburton.*

Victoria.—North-West: Between Cohuna and Kerang, May, 1944, *R. V. Smith;* Berribee Tank, far NW. corner of State (in a large claypan 2 miles east), 31st Aug., 1948, *J. H. Willis.*

New South Wales.—Far Western Plains: Junction of Murray and Darling Rivers, 1889, *Mrs. Holding.* Western Plains: Warrego River, *E. Betche.*

The epithet of the new name (rendered necessary by preoccupation of the name *Erechthites picridioides*) is in allusion to the remarkable, retrorsely-lobed leaves of this plant that resemble those of a dandelion (*Taraxacum* species). It would seem to be riparian and, in view of the scanty material available in Australian herbaria, is apparently rare. The original diagnosis, drawn up from poor "starved" specimens, gives a completely inadequate picture of the species and an amended and amplified description follows:

Herb, pale green, glabrescent, 20–40 cm. high (6 ins. in original description), the young parts and leaf axils slightly cottony-woolly. *Leaves* sessile, lanceolate acuminate, with up to 8 more or less reversed sinuate-lobed segments on each side, to 12 cm. long and 3 cm. wide at base of stems (1 in. and 3–4 lin. in original description); upper floral leaves less toothed, with long, almost filiform tips. *Panicle* corymbose, loose, up to 60-headed (6–8 in original description). Peduncles of each head slender, up to twice the length of involucre which is minutely cottony, bracteolate at the base. *Phyllaries* of involucre 12–14, about 1 cm. long, linear, acute, glabrous in fruit. *Corolla* tube of central hermaphrodite florets about 0·5 mm. diameter at base of the 5 lobes, about 4 times wider than the tubular filiform female florets; lobes in both with shortly papillose margins. *Achene* 2·5–3 mm. long, pallid, slightly flattened (about 0·3 mm. wide), with about 9 costae that bear short, erect, papillate hairs—without the attenuated beak ascribed to it in the original diagnosis. *Anthers* about 1 mm. long, without basal appendages. *Style arms* ligulate, about 0·33 mm. long, with swollen, recurved apices, coarsely papillose on inner face. Pollen grains sharply echinulate, 20–25 mic. diameter.—Plate VII, figs. 34–37.

All the collections cited are in Melbourne Herbarium, but Bentham saw only the South Australian ones. It is astonishing he should have confused *E. picridioides* Sonder & F. Muell. with *E. mixta* (A. Rich.) DC.—a purplish mountain plant of entirely different aspect and floral structure. J. M. Black (1929) perpetuated the confusion.

[Mr. A. O. Belcher (Michigan) is revising *Erechthites* Rafin., and many changes are anticipated in the nomenclature of Australian species hitherto referred to this genus.]

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MAIDEN, J. H., AND BAKER, R. T., 1895. Proc. Linn. Soc. N.S. Wales **10**: 589, 590.

EXPLANATION OF PLATE VII.

Figs. 1-7, *Helichrysum eriocephalum* sp. nov. — 1, branch with inflorescence (½ nat. size); 2, capitulum; 3, upper involucral bract; 4, central floret; 5, tip of pappus bristle; 6, style arms; 7, anther.

Figs. 8-10, *H. cordatum* DC. (upper bract, central floret and pappus bristle—*cf.* figs. 3-5).

Figs 11-13. *H. ramosum* DC. (upper bract, central floret and pappus bristle—*cf.* figs. 3-5).

Figs. 14-20, *Helichrysum tuckeri* sp. nov. — 14, branch with inflorescences (½ nat. size); 15, capitulum; 16, upper involucral bract; 17, central floret; 18, tip of pappus bristle; 19, anther; 20, leaves (enlarged).

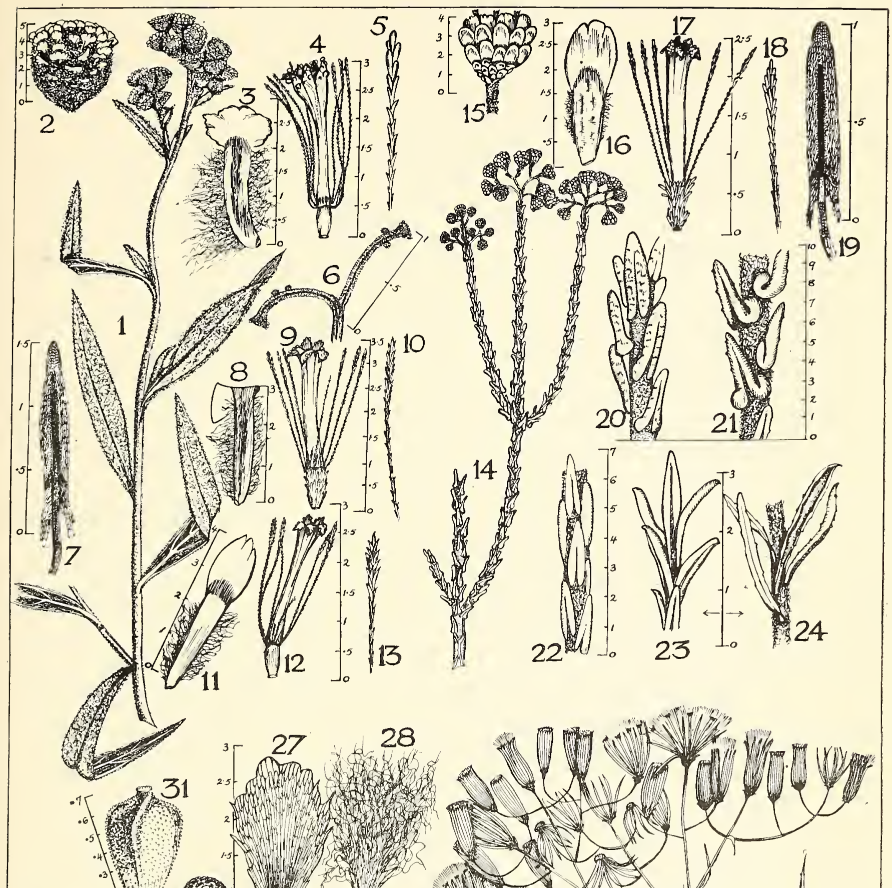
Figs. 21-22, enlarged leaves of *H. diotophyllum* F. Muell. and *H. adnatum* (DC.) Benth. respectively.—*cf.* with fig. 20.

Figs. 23-24, leaves of *H. tesselatum* Maiden & Baker and *H. diosmifolium* (Vent.) Sweet, respectively (¾ nat. size).—*cf.* figs. 20-22.

Figs. 25-33 *Chthonocephalus multiceps* sp. nov. — 25, plant (½ nat. size); 26, flagellate hairs on leaf surfaces; 27, hairless inner involucral bract of partial head; 28, outer bract of partial head; 29, uppermost floret, with hairy subtending scale and reduced pappus; 30, lower floret, with normal pappus; 31, triquetrous achene; 32, style; 33, anther (inserted on corolla tube).

Figs. 34-37, *Senecio runcinifolius* nom. nov. — 34, branch with an inflorescence (½ nat. size); 35, outer female and central hermaphrodite florets; 36, style arms; 37, anther.

[Except in figs. 1, 14, 25 and 34, a scale in millimetres accompanies each drawing; the scale for figs. 23-24 is in centimetres.]



SOME AUSTRALIAN COMPOSITAE.

WHITEOCHLOA, A NEW GENUS OF GRASSES FROM THE NORTHERN TERRITORY OF AUSTRALIA.

By C. E. **Hubbard**, Royal Botanic Gardens, Kew, England.

(*Issued separately, 22nd August, 1952.*)

SUMMARY.

Whiteochloa, a new genus of Gramineae, tribe Paniceae, is described.

The tribe *Paniceae* of the family *Gramineae* is exceptionally well-developed in the warmer parts of Australia, no fewer than thirty-nine genera now being recorded as native or naturalized and well-established, a very considerable increase on the thirteen described by Bentham in the Flora Australiensis (1878). This trebling of the number of genera is due mainly to a more uniform conception of these taxa than that adopted by Bentham, the genus being now restricted to species very similar in the structure and arrangement of their spikelets, and presenting a distinctive facies. Thus D. K. Hughes (1923), in her revision of the genus *Panicum* of the Flora Australiensis accepted the genera defined by A. Chase and by Stapf as a result of their studies of American and African *Paniceae* respectively, and divided the species of *Panicum* sensu Bentham among fourteen genera. Further subdivision has been carried out by S. T. Blake in segregating his new genera *Zygochloa* from *Spinifex* and *Ancistrachne* from *Panicum*, and by Pilger in removing *Pseudoraphis* from *Chamaeraphis*. On the other hand, several additions to the Australian genera of *Paniceae* are due to more intensive collecting in botanically unexplored areas; they include the genera *Calyptochloa, Cleistochloa, Dimorphochloa, Homopholis, Ottochloa, Pseudochaetochloa* and *Uranthoecium*. A few exotic genera introduced as fodder plants, such as *Axonopus, Melinis* and *Rhynchelytrum*, have become established in the warmer parts of the Commonwealth.

The most important characters used in distinguishing the genera of the *Paniceae* are to be found in those modifications of the scales of the spikelet which ensure greater protection or more widespread dispersal of the seed, in those produced by lateral or dorsal pressure during the development of the spikelet, in the degree of development of the lower floret, in the arrangement of the spikelets in the inflorescence and in the form of the latter. Among the Australian species referred to the genus *Paspalidium* Stapf by Hughes, is one, *P. semitonsum* (F. Muell. ex Benth.) Hughes (l.c. 317), which differs from all other members of the genus in so many of these diagnostic characters that it must be separated as a distinct genus. The name *Whiteochloa* is proposed for this new genus. The distinctions between the two genera are set out in the following table:—

PASPALIDIUM.	WHITEOCHLOA.
1. Spikelets plano-convex or slightly dorsally compressed.	1. Spikelets slightly laterally compressed.
2. Upper floret sessile on the rhachilla.	2. Upper floret borne on a very short rhachilla-internode.
3. Lower glume abaxial; upper glume adjacent to the axis on which the spikelet is borne.	3. Lower glume adaxial, adjacent to the axis on which the spikelet is borne.
4. Upper glume glabrous.	4. Upper glume bearing a row of stiff tubercle-based hairs on each nerve.
5. Lower lemma usually flat or slightly depressed on the back.	5. Lower lemma very convex on the back except for a very narrow shallow median translucent longitudinal groove.
6. Upper floret about as long as the lower.	6. Upper floret shorter than the lower.
7. Axes of the inflorescence each terminated by a bristle or blunt naked tip.	7. Axes of the inflorescence each terminated by a spikelet.

Judging from the orientation of its spikelets and by their general structure, *Whiteochloa* is more closely related to *Pseudechinolaena* Stapf than to *Paspalidium*. This genus of forest grasses has been recorded from Papua and may occur in the rain forests of northern Queensland. It comprises two species, *Pseudechinolaena polystachya* (H.B.K.) Stapf, with a wide area of distribution in tropical America, Africa and Asia, and *P. perrieri* A. Camus, which is confined to Madagascar. The two genera may be distinguished by the following characters:—

PSEUDECHINOLAENA.	WHITEOCHLOA.
1. Glumes equal, herbaceous, or the lower slightly shorter, rarely only two-thirds the length of the spikelet.	1. Glumes unequal, membranous, the lower one-third to half the length of the spikelet.
2. Upper glume with more or less translucent spots between the nerves, and usually with a straight or eventually hooked many-celled bristle-like outgrowth from the centre of each spot.	2. Upper glume bearing a row of stiff tubercle-based unicellular white hairs along each nerve.
3. Lower lemma convex on the back.	3. Lower lemma convex on the back except for a narrow median groove.
4. Ligules membranous.	4. Ligule reduced to a ciliate rim.
5. Leaf-blades lanceolate to ovate, short.	5. Leaf-blades narrowly linear, elongated.

It is very probable that the two genera differ much in habit, the species of *Pseudechinolaena* being trailing annuals or perennials, branching and rooting from the prostrate many-noded base, and with very slender ascending leafy culms. Unfortunately the type-material of *Whiteochloa* lacks the base, but it has the appearance of an erect or suberect annual, with simple few-noded culms.

The genus *Ancistrachne* S. T. Blake resembles *Whiteochloa* in some respects, but may be readily separated by its rigid woody branched culms, the slightly dorsally compressed abaxial spikelets, 9-11-nerved upper glume, barren lower floret, 7-9-nerved lower lemma and by the flattened margins of the upper lemma. The genus *Brachiaria,* which agrees with *Whiteochloa* in possessing adaxial spikelets, may be distinguished by its terete or dorsally compressed spikelets, sessile upper floret, absence of tubercle-based hairs on the nerves of the upper glume, and by the thin median groove of the coriaceus lower lemma.

Generic Description.

Whiteochloa *C. E. Hubbard,* genus novum, affine *Pseudechinolaenae* Stapf, sed glumis membranaceis, gluma inferiore late ovata usque dimidiam partem spiculae aequante, gluma superiore secus nervos pilis brevibus rigidiusculis e tuberculis minutis ortis ciliata, lemmate infero dorso longitudinaliter sulcato, ligula ad seriem ciliorum redacta, laminis foliorum anguste linearibus differt.

Spiculae asymmetricae, a laterae visae semi-ovatae vel semi-elliptico-ovatae, a dorso visae anguste ellipticae et acutae, exaristatae, leviter lateraliter compressae, contiguae vel imbricatae, adaxiales, breviter et inaequaliter pedicellatae, demum totae a pedicellis persistentibus disarticulantes, solitariae vel binae, in ramis et ramulis secundis panicularum erectarum linearium vel lanceolatarum dispositae; rami gracillimi, triquetri, solitarii, inferne ramulos breves appressos paucispiculatos gerentes; rhachilla inter anthoecia internodio gracillimo brevissimo glabro praedita. *Anthoecia* duo, dissimilia; inferum masculum; superum hermaphroditum, infero brevius. *Glumae* inaequales, dissimiles; inferior usque dimidiam partem spiculae aequans, late ovata, obtusa vel acuta, mucronulata, membranacea, 3-5-nervis; superior spiculae aequilonga vel fere aequilonga, cymbiformis, dorso valde convexa, explanata anguste ovata, acute acuminata, membranacea, 5-7-nervis, nervis pilis brevibus patulis rigidiusculis e tuberculis minutis ortis ciliata. *Anthoecium inferum:* lemma spiculae aequilongum vel fere aequilongum, dorso longitudinaliter anguste sulcatum, ceterum convexum, sulco translucente excepto coriaceum, elliptico-oblongum, subacutum vel obtusum, tenuiter 5-nerve, glabrum vel fere glabrum, palea anguste elliptica vel oblonga, lemmati aequilonga vel eo paullo longior, obtusa, bicarinata, circa carinas anguste alatas indurata, ceterum tenue membranacea. *Anthoecium superum* a latere visum semi-elliptico-ovatum, a dorso visum anguste ellipticum et acutum: lemma apiculatum, dorso valde convexum, marginibus involutis angustis firmis, demum crustaceum, tenuiter 5-nerve, tenuiter transverse rugulosum; palea lemmati aequilonga, dorso plana, crustacea, 2-nervis. *Lodiculae* 2, late oblongae, truncato-emarginatae, glabrae. *Stamina* tria; antherae anguste oblongae. *Ovarium* glabrum; styli liberi, terminales; stigmata breviter plumosa. *Caryopsis* a dorso visa elliptica, dorso compressa, plano-convexa; scutellum circiter dimidiam partem caryopseos aequans; hilum basale, ellipticum.—*Culmi* graciles, erecti, simplices; foliorum vaginae anguste lineares, planae; ligulae ad seriem ciliorum redactae; paniculae elongatae.

Species unica, Australiae tropicae incola.

Whiteochloa semitonsa (*F. Muell. ex Benth.*) *C. E. Hubbard,* comb. nov.

Panicum semitonsum F. Muell. ex Benth. Fl. Austral. **7**: 483 (1878); Ewart & Davies, Fl. North. Territ. 39 (1917).

Paspalidium semitonsum (F. Muell. ex Benth.) Hughes in Kew Bull. **1923**: 317 (1923).

Gramen annum (?), basis ignotum, circiter 60 cm. altum. *Culmi* glabri, laeves. *Foliorum vaginae* marginibus apicem versus ciliolatae, ceterum glabrae; laminae usque 12 cm. (vel ultra) longae, 3.5 mm. latae, supra minute scaberulae, glabrae. *Inflorescentia* 10-20 cm. longa, usque 5 cm. lata; rami inferiores usque 7 cm. longi; pedicelli 0·3–2 mm. longi. *Spiculae* 3·5–4·2 mm. longae; internodium rhachillae usque 0·5 mm. longum; gluma inferior 1·5–2 mm. longa, nervis minute hispidula; anthoecium superum 2·2–2·5 mm. longum; antherae 1·3–1·5 mm. longae.

NORTHERN TERRITORY: Victoria River, *Elsey!* (Herb. Kew.).

In addition to the above, Bentham (l.c.) also cites a specimen collected by F. Mueller at Providence Hill, north of the mouth of the Victoria River, at about 14° 30′ S and 129° 30′ E. This material was probably returned to the Melbourne Herbarium. Both J. R. Elsey's and F. Mueller's specimens were gathered on A. C. Gregory's Northern Australian Expedition of 1855-56, on which the former served as surgeon and naturalist and the latter as botanist.

The name *Whiteochloa* is given in memory of Cyril Tenison White, one of Australia's most illustrious botanists. He is remembered by the writer with gratitude and affection as a very good friend, who by his generous help, kindly advice and encouragement, and perfect companionship on numerous botanical excursions, made most memorable a year spent at the Brisbane Herbarium and elsewhere in Queensland in 1930-31.

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The Royal Society of Queensland.

Report of the Council for 1949.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting the Annual Report of the Society for the year 1949.

At Ordinary Meetings throughout the year five addresses were given, one film was shown, and one exhibit evening held; while on one occasion a report was made on the Science House project. The Annual Memorial Lecture, held this year in honour of Mr. F. M. Bailey, was delivered by Mr. C. T. White. Eight original papers were accepted for publication in the Proceedings.

An approach was made to the Premier and Chief Secretary's Department for an increase in the maximum yearly subsidy payable on publication, and an increase from £150 to £200 was granted.

To overcome the delay in publication of the Proceedings, the Council has decided, in agreement with the Government Printing Office, to have the Volume for 1949 printed by an outside firm, in which case the Government subsidy will still be available.

The Society has obtained sole occupancy of the room in which the Library is housed, and additional shelving has been constructed. The Library is now in quite good order, but still requires cataloguing.

There are 5 honorary life members, 9 life members, 3 corresponding members, 234 ordinary members and 1 associate member in the Society. This year the Society has lost 1 member by death and 10 by resignation; 22 ordinary members and 1 associate member have been elected, and 1 member has been readmitted.

Attendance at Council Meetings was as follows:—D. Hill, 10; H. C. Webster, 9; M. F. Hickey, 7; M. I. R. Scott, 10; D. F. Sandars, 9; B. Baird, 8; S. T. Blake, 9; G. Mack, 7; O. A. Jones, 9; A. L. Reimann, 7; J. H. Simmonds, 5; L. J. H. Teakle, 5; E. M. Shepherd, 8.

DOROTHY HILL, President.

MARGARET I. R. SCOTT. Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31ST DECEMBER, 1949.

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Commonwealth Bank, 31st December, 1948	216	4	7			
Cash in hand, 31st December, 1948	6	10	2			
				222	14	9
Subscriptions, 1949	208	6	6			
Arrears	64	1	0			
Paid in Advance	10	5	0			
				282	12	6
Commonwealth Loan Interest	7	1	10			
Savings Bank Interest	4	15	2			
				11	17	0
Grant from Zinc Corporation for Paper by A. Beasley				60	0	0
Sale of Reprints				27	5	8
Sale of Royal Society Proceedings				24	17	6
Exchange				0	14	6
				£630	1	11

EXPENDITURE.

	£	s.	d.	£	s.	d.
Government Printer—						
Cost of Vol. LIX., Parts I. and II.	457	6	10			
Amount paid in 1948	191	16	7			
	265	10	3			
Less Government Subsidy	150	0	0			
				115	10	3
Library Insurance				0	19	3
Roneoing				5	15	0
Lanternist				3	0	0
Special Manilla Envelopes				11	15	1
Octavo Envelopes				6	16	6
Wreath—late Mr. E. Bick				1	1	0
Refreshments and Utensils	8	1	8½			
Less collections	5	15	11			
				2	5	9½
Stationery, stamps, &c.—						
Hon. Secretary	19	3	9			
Hon. Treasurer	0	2	10			
				19	6	7
Balance in Commonwealth Bank	454	1	7			
Cash in Hand, 31st December, 1949	9	11	10½			
	463	13	5½			
Less cash overbanked, 11th November, 1949	0	1	0			
				463	12	5½
				£630	1	11

In addition to the Credit Balance shown in the above Statement, the Society holds the following Capital Funds:—

Commonwealth Loan	200
Savings Certificates	2
	£202

held in safe custody by the Commonwealth Bank of Australia, Queen street, Brisbane.

Examined and found correct.

L. P. HERDSMAN, Hon. Auditor.

DOROTHEA SANDARS, Hon. Treasurer.

15th March, 1950.

ABSTRACT OF PROCEEDINGS, 27TH MARCH, 1950.

The Annual General Meeting of the Society was held in the Geology Department of the University on Monday, 27th March, with the President (Dr. Dorothy Hill) in the chair. About forty-five members and friends were present. Apologies were received from His Excellency the Governor, Prof. Bostock, Dr. Nye and Mr. Longman. The Minutes of the last Annual General Meeting were read and confirmed. The Annual Report was adopted and the Balance-sheet received. The following were nominated for membership:—Mr. F. W. Berrill, Dr. Ernest Singer, Mr. R. F. Isbell, Mr. G. A. Wyatt, Mr. I. F. Fergus and Mr. J. D. Hughes for Ordinary Membership, and Miss B. Howard, Miss M. Patey, Miss J. W. Herbert, Miss D. J. Matthews and Miss H. M. Simmons for Associate Membership.

The following officers were elected for 1950:—

President: Prof. M. F. Hickey.

Vice-President: Prof. H. J. G. Hines.

Hon. Secretary: Miss M. I. R. Scott.

Hon. Treasurer: Miss D. F. Sandars.

Librarian: Mr. F. S. Colliver.

Editors: Mr. S. T. Blake, Mr. G. Mack.

Members of Council: Dr. I. M. Mackerras, Prof. A. L. Reimann, Mr. J. H. Simmonds, Prof. L. J. H. Teakle, Prof. H. C. Webster.

Hon. Auditor: Mr. L. P. Herdsman.

The Presidential Address, entitled "The Earliest Corals," was delivered by Dr. Dorothy Hill. A vote of thanks was moved by Prof. F. W. Whitehouse, seconded by Prof. W. H. Bryan and carried by acclamation.

ABSTRACT OF PROCEEDINGS, 24TH APRIL, 1950.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 24th April, with the President (Professor M. F. Hickey) in the chair. About sixty members and friends were present. The minutes of the previous meeting were confirmed. The following members were elected:—Ordinary Members—Mr. F. W. Berrill, Dr. Ernest Singer, Mr. R. F. Isbell, Mr. G. A. Wyatt, Mr. I. F. Fergus, Mr. J. D. Hughes, Miss D. J. Matthews and Miss H. M. Simmons; Associate Members—Miss B. Howard, Miss M. Patey and Miss J. W. Herbert. Miss Matthews and Miss Simmons, who had been nominated as Associate Members in error, had consented to stand for election as Ordinary Members. The following nominations for ordinary membership were received:—Mr. W. G. Burns, Mr. M. Strohfeldt, Mr. J. A. Thomas, Mr. D. Sinclair, and Mr. M. Crawfoot. The Clarke Memorial Medal for 1950 was presented on behalf of the Council of the Royal Society of New South Wales to Dr. Ian M. Mackerras.

Dr. Owen Jones gave a lecture on "The Use of Seismographs in the Detection of Cyclones." The method utilizes three sensitive seismographs set up at the apices of an equilateral triangle. The bearing of the storm-centre is calculated from the differences in time of arrival of an identical microseismic wave at the three instruments. The position of the centre is fixed by intersection of bearings from two or more stations. Professor W. H. Bryan was the first (in 1938) to note the correlation of microseisms and hurricanes. Since then work at the University of Queensland Seismological Station has shown:—

(1) That, even with our present instruments, which are not as sensitive as those used by the U.S. Navy, we can detect hurricanes.

(2) That, in some cases at least, we can detect their presence before they can be detected by the methods now in use by the Weather Bureau.

(3) That we can distinguish between malevolent and beneficent cyclones.

(4) That the use of microseisms would be a valuable supplement to the present methods of locating and following the course of hurricanes.

We cannot, however, locate them, that is, determine the bearing of the centre. For that we need more seismographs of an even more sensitive type. To equip four stations in Queensland would cost about £28,000 and about £500 per year in upkeep.

Abstract of Proceedings, 22nd May, 1950.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 22nd May, with the President (Dr. M. F. Hickey) in the chair. About thirty-five members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Ordinary Membership:—Mr. W. G. Burns, Mr. M. Strohfeldt, Mr. J. A. Thomas, Mr. D. Sinclair and Mr. M. Crawfoot.

Dr. E. J. Reye exhibited some live plankton from Moreton Bay.

Three short addresses were given by Dr. M. F. Hickey, Professor A. L. Reimann and Miss D. Sandars, respectively.

In discussing "Some Aspects of Congenital Abnormalities," Dr. Hickey gave a brief illustrated account of the development of the fertilized human ovum to the stage of the three-layered embryonic disc, and indicated the various ways in which it was thought that identical twins might develop during these early stages and how certain of the forms of so-called "Siamese twins" probably developed. He indicated the difficulty of establishing ultimate causes, but pointed out that the work of Streeter, Douglas Murphy and others leads to the general conclusion that gross human congenital malformations arise solely from influences which affect the germ cells prior to fertilization. But in the case of fishes, amphibia and birds, it appeared that malformations could be produced in the developing embryo by alterations of the environment—chemical, physical and thermal.

Professor Reimann spoke on electron gases. The properties of ordinary and electron gases were compared and contrasted, with special reference to (*a*) condensation, evaporation and latent heat; (*b*) winds;

and (*c*) the distribution of thermal velocities. Under (*a*) it was pointed out that as in the case of the molecules of ordinary gases, so also electrons may be obtained in the free state by evaporating them from a condensed phase, e.g., from metals (thermionic emission), and that a latent heat of evaporation has to be supplied to bring this about, this being related to the thermionic work function. Under (*b*) it was shown that the operation of electronic devices such as radio valves, X-ray tubes, cathode-ray tubes and electron microscopes depends on the control of electron ''winds'' derived from a thermionic cathode and directed, by appropriate electric or magnetic fields, to an anode, in which latter they are condensed. Under item (*c*), it was shown how, in principle, the range of gas thermometry, on which our standard scale of temperature is based, might be extended far beyond the upper practical limit for ordinary gases, viz., about 1,500 deg. C., by using an electron gas in place of an ordinary gas such as nitrogen. Electron-gas thermometry would have to be based on the theoretical relation between velocity distribution of emission and temperature, the former being explored by the application of various retarding potentials to the anode. In this way gas thermometry could be extended to near the melting point of tungsten (about 3,400 deg. C.).

Miss Sandars spoke on the Great Barrier Reef Committee's proposal for a marine biological station. She said that the committee has decided to establish a marine biological station on the Reef for research into reef biology and associated problems, for training young research workers, and for research into marine economic problems. It could also serve as a centre for other scientific investigations. Heron Island (Capricorn Group) has been chosen as the site for the station, and draft plans of the building and estimates of costs have been prepared. The proposals have been approved by A.N.Z.A.A.S., A.N.R.C., C.S.I.R.O., The Pacific Science Association, the Royal Society and the Royal Geographical Society. The estimated capital cost is £5,000 for building and £500 for basic equipment. Already £2,468 14s. 1d. has been received, including £1,000 stg. from the M. T. Browne fund of the Royal Society, £500 from the Great Barrier Reef Committee, £517 9s. 1d. from the Goddard Memorial Fund, and £201 5s. from other organisations and private donations. The Government has accepted gifts to the fund as rebatable for taxation purposes, and the Committee is now seeking to augment it substantially by individual donations. The support of the Royal Society of Queensland was expressed in the following motion, proposed, seconded and carried unanimously:—

> ''That the Royal Society of Queensland commends the proposal of the Great Barrier Reef Committee to establish a marine biological station on the Reef and offers its influence in support of the project.''

Abstract of Proceedings, 26th June, 1950.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 26th June, with the President (Dr. M. F. Hickey) in the chair. About forty members and friends were present. The minutes of the previous meeting were confirmed. The following were nominated for Membership:—Mr. J. P. Webb and Miss Rona E. Stewart—Ordinary Members; Mr. J. S.

Derrington, Mr. C. W. Siller, Mr. I. R. McLeod, Mr. J. B. Jones, Mr. A. R. Lloyd, Mr. J. P. Stephenson and Mr. K. G. Smith—Associate Members.

Dr. E. Singer gave an address entitled "Four Years in China."

ABSTRACT OF PROCEEDINGS, 31ST JULY, 1950.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 31st July, with the President (Dr. M. F. Hickey) in the chair. About forty members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to membership:—Mr. J. P. Webb, Miss R. E. Stewart—Ordinary Members; Mr. J. S. Derrington, Mr. C. W. Siller, Mr. I. R. McLeod, Mr. J. B. Jones, Mr. A. R. Lloyd, Mr. J. P. Stephenson, Mr. K. G. Smith—Associate Members. The following were nominated for Associate Membership:—Miss J. von Alpen, Miss C. Goldsmid, Mr. W. R. Dowd.

The President made the following announcement regarding the death of Dr. Gustave Athol Waterhouse. "I regret to announce that Dr. Gustave Athol Waterhouse died in Sydney on the 29th July. He was not a member of this Society; but he was well known to many members as an authority on Australasian Lepidoptera, and he was for many years prominent in the councils of our sister Royal Society in New South Wales, as well as of the Linnaean Society, the Australian National Research Council, and other scientific organisations. Our sympathy is extended to his family."

The Librarian reported that 76 additional volumes and parts had been added to the library since the last meeting. Also a new exchange has been established for the Comptes Rendus d'Académie des Sciences, Bulgaria.

The following paper was presented:—"*Aphistomyia collini* Bezzi (Diptera, Blepharoceridae) in North Queensland" by I. M. Mackerras and M. J. Mackerras.

Professor W. Stephenson gave an address entitled "Preliminary Observations upon the Evolution of Phosphates from Estuarine Muds." Some of the difficulties of this type of investigation, even when undertaken under laboratory conditions, were detailed. Muds sometimes absorb phosphate, and sometimes release it, and the presence of animals in the mud may increase absorption or initiate release. Evolution of phosphate from surface deposits of mud proceeds rapidly under conditions of oxygen lack, and as previously shown (1949), phosphate may be evolved from mud and mud filtrates merely by agitation.

ABSTRACT OF PROCEEDINGS, 4TH SEPTEMBER, 1950.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 4th September, with the President (Dr. M. F. Hickey) in the chair. About thirty-six members and friends were present. The minutes of the previous meeting were confirmed. Miss C. Goldsmid and Miss J. von Alpen were elected to Associate Membership.

A film entitled "Smoke Streams" was shown, a commentary being given by Mr. G. Birkbeck.

Professor M. Shaw exhibited partially made experimental models of a cutting-tool dynamometer for measuring steady and also transient cutting forces, and a profilometer for measuring surface finish.

Professor W. H. Bryan exhibited a fossilized branch of a coniferous tree in the shape of a hollow mould 27 cm. in length and 5 cm. in breadth from the lower (non-welded) part of the Brisbane Tuffs as developed at Butterfield road, near the Brisbane General Hospital. The fossil was from approximately the same horizon as that in which numerous fossil trees have been found, the petrified wood of which is, in most cases, closely comparable with that of modern conifers such as *Araucaria.*

Professor D. A. Herbert exhibited (*a*) portions of the trunks of two rain-forest saplings that had covered encircling vines with callus and continued to grow with the vine stems apparently entering below and emerging further up, (*b*) a trunk of *Myrtus hillii* which had grown over a vine lying in a fork so that the vine stem appeared to be growing through the wood, and (*c*) some dressed planks of hoop pine (*Araucaria cunninghamii*) with vines deeply embedded and covered with several inches of wood. In the hoop pine specimens the result was curious in that knots of dicotyledonous wood were in the gymnosperm timber.

Dr. M. F. Hickey exhibited some micro-photographs in colour of sections of tissue showing the large multi-nucleated cells usually called Osteoclasts (various magnifications up to x 850). The slides illustrated the great variety of shape of these cells, their situation as usually described, i.e., at areas of bone absorption, but also apparently in areas where bone deposition was in its earliest stage, and some in sites apparently remote from bone formation. Some of the cells showed marked pseudopodial processes. The speaker referred to a review of the problem of the Osteoclast by Hancox containing an extensive list of references in Biol. Rev., Vol. 24, pp. 448–471, October 1949.

ABSTRACT OF PROCEEDINGS, 25TH SEPTEMBER, 1950.

The Ordinary Monthly meeting of the Society was held in the Geology Department of the University on Monday, 25th September, with the President (Dr. M. F. Hickey) in the chair. About eighty members and friends were present. The minutes of the previous meeting were confirmed. Mr. R. H. Greenwood was nominated for Ordinary Membership. The Librarian reported the addition of about ninety volumes and parts to the Library since the last meeting. Mr. L. C. Ball was elected to Honorary Life Membership. Mr. W. P. Dowd was elected to Associate Membership.

Three films were shown:—

(1) "In All Weathers."
(2) "Wonders of the Deep."
(3) A film of marsupial mice.

Abstract of Proceedings, 30th October, 1951.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 30th October, with the President (Dr. M. F. Hickey) in the chair. About sixty members and friends were present. The minutes of the previous meeting were confirmed. Mr. R. H. Greenwood was elected to Ordinary Membership. Dr. G. C. Kenny and Mr. C. G. Ludford were nominated for Ordinary Membership. The Librarian reported that 89 volumes and parts have been added to the Library since the last meeting; also two new exchanges, Die Erde and Ann. Fac. des Sciences de Marseille, have been established.

Mr. F. S. Colliver exhibited, on behalf of the Geology Department, parti-coloured tourmaline crystals from Arizona.

Professor F. W. Whitehouse exhibited a late Tertiary basalt collected by Mr. Ogilvie north of Hughenden, showing curious radial rosette structures only doubtfully of spherulitic origin.

Professor J. T. Wilson, of Toronto, gave an address entitled "The Growth of a Continent."

Abstract of Proceedings, 27th November, 1950.

The Ordinary Monthly Meeting of the Society was held in the Geology Department of the University on Monday, 27th November, with the President, Associate Professor M. F. Hickey, in the chair. About thirty members and friends were present. The minutes of the previous meeting were confirmed. Dr. G. C. Kenny and Mr. C. G. Ludford were elected to Ordinary Membership. Professor T. K. Ewer and Professor F. T. M. White were nominated for Ordinary Membership. The Librarian reported that 122 volumes and parts had been added to the Library; also new exchanges had been established for the Pakistan Journal of Science, the Records of the South Australian Museum, and Zoological Papers of Victoria College, New Zealand; in addition, holdings of the Ohio Journal of Science and the Royal Society of Tasmania have been completed.

Miss D. F. Sandars exhibited the contents of a bandicoot's stomach.

Professor W. H. Bryan exhibited specimens of turquoise collected by Dr. O. A. Jones and himself from a cutting in Adelaide street, in the heart of the city of Brisbane. (This is probably the same locality as that recorded by Major Sankey many years ago.) He pointed out that turquoise and wavellite have also been rediscovered at Wilston Hill and at Stafford, but Sankey's locality at Victoria Park has not been found. Mr. A. K. Denmead commented on the exhibit.

Professor M. Shaw gave an address entitled "Graticules and their Production." In his opening remarks he gave the reasons for choosing a certain design of graticule and the thickness of the lines in the pattern. For example, a telescope sight for a jungle rifle must have a very thick line to stand out against the confused background, whereas a theodolite may have a very fine line of about 0·0001 in. in width. Various types of graticules were shown and explained both by means of illustrations on the screen and also by the graticules themselves which were on show. The speaker then went on to describe the methods used in the manufacture of graticules of both the photographic and the ruled and etched type. He spent some time explaining the instruments which had been developed in the University of Melbourne, and illustrated his remarks by an interesting ''Heath Robinson'' wooden model which demonstrated in a very simple manner all the principles involved in the extremely accurate prototype. Both the line-ruling and the pantograph machines were explained. A full discussion followed which was amplified by the remarks elicited as a result of a close examination of the exhibit by the audience. A full account of this work is to be obtained in the Proceedings of the Institution of Mechanical Engineers 160: 145 (1949).

ALTERATIONS TO MEMBERSHIP.

NEW HONORARY LIFE MEMBER.

Ball, L. C.

NEW ORDINARY MEMBERS.

Berrill, F. W.	..	Department of Agriculture and Stock, Nambour.
Burns, W. G.	..	Geology Department, University, Brisbane.
Crawfoot, A.	..	Geology Department, University, Brisbane.
Fergus, I. F.	..	Department of Agriculture and Stock, Brisbane.
Greenwood, R. H.	..	Geography Department, University, Brisbane.
Hughes, J. D.	..	Department of Agriculture and Stock, Brisbane.
Isbell, R. F.	..	Geology Department, University, Brisbane.
Kenny, Dr. G. C.	..	Anatomy Department, University, Herston.
Ludford, C. G.	..	Queensland Institute of Medical Research, Herston road, Brisbane.
Matthews, Miss D. J.		Botany Department, University, Brisbane.
Simmons, Miss H. M.		Botany Department, University, Brisbane.
Singer, Dr. E.	..	Ivy street, Indooroopilly.
Stewart, Miss R. E.	..	Queensland Institute of Medical Research, Herston road, Brisbane.
Strohfeldt, M.	..	Radio Physics Laboratory University Grounds, City road, Chippendale, N.S.W.
Thomas, J. A.	..	Physics Department, University, Brisbane.
Webb, J. P.	..	Geology Department, University, Brisbane.
Wyatt, G. A.	..	Department of Agriculture and Stock, Brisbane.

NEW ASSOCIATE MEMBERS.

Derrington, J. S.	..	423 Milton road, Auchenflower.
Dowd, W. R.	..	Coronation drive, Auchenflower.
Goldsmid, Miss C.	..	30 Eblin drive, Hamilton.
Herbert, Miss J. W.	..	Botany Department, University, Brisbane.
Howard, Miss B.	..	Physiology Department, University, Brisbane.
Jones, J. B.	..	Geology Department, University, Brisbane.
Lloyd, A. R.	..	Geology Department, University, Brisbane.
McLeod, I. R.	..	Geology Department, University, Brisbane.
Patey, Miss M.	..	Physiology Department, University, Brisbane.
Siller, C. W.	..	Geology Department, University, Brisbane.
Smith, K. G.	..	Geology Department, University, Brisbane.
Stephenson, J. P.	..	Geology Department, University, Brisbane.
von Alpen, Miss J.	..	Biochemistry Department, University, Brisbane.

RESIGNATIONS.

Bosworth, F. O.
Gipps, R. de V.
Jones, W. M.
Lee, Dr. D. K.
Machin, W. F.
Noyes, Miss M.
Tuffley, Mrs. A. M.

DEATHS.

White, C. T.
Henderson J. B.

A. H. TUCKER, Government Printer, Brisbane.

GUIDE FOR THE PREPARATION OF SYNOPSES

1. PURPOSE.

It is desirable that each paper be accompanied by a synopsis preferably appearing at the beginning. This synopsis is not part of the paper; it is intended to convey briefly the content of the paper, to draw attention to all new information and to the main conclusions. It should be factual.

2. STYLE OF WRITING.

The synopsis should be written concisely and in normal rather than abbreviated English. It is preferable to use the third person. Where possible use standard rather than proprietary terms, and avoid unnecessary contracting.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The synopsis should therefore be intelligible in itself without reference to the paper, for example it should not cite sections or illustrations by their numerical references in the text.

3. CONTENT.

The title of the paper is usually read as part of the synopsis. The opening sentence should be framed accordingly and repetition of the title avoided. If the title is insufficiently comprehensive the opening should indicate the subjects covered. Usually the beginning of a synopsis should state the objective of the investigation.

It is sometimes valuable to indicate the treatment of the subject by such words as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

It should contain the names of any new compound, mineral, species, etc., and any new numerical data, such as physical constants; if this is not possible it should draw attention to them. It is important to refer to new items and observations, even though some are incidental to the main purpose of the paper; such information may otherwise be hidden though it is often very useful.

When giving experimental results the synopsis should indicate the methods used; for new methods the basic principle, range of operation and degree of accuracy should be given.

4. DETAIL OF LAYOUT.

It is impossible to recommend a standard length for a synopsis. It should, however, be concise and should not normally exceed 100 words.

If it is necessary to refer to earlier work in the summary, the reference should always be given in the same manner as in the text. Otherwise references should be left out.

When a synopsis is completed, the author is urged to revise it carefully, removing redundant words, clarifying obscurities and rectifying errors in copying from the paper. Particular attention should be paid by him to scientific and proper names, numerical data and chemical and mathematical formulae.

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Vol. LXII.

C. T. WHITE MEMORIAL SUPPLEMENT.

PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

QUEENSLAND

FOR 1951

VOL. LXIII.

ISSUED 17th AUGUST, 1953

PRICE: TWENTY-FIVE SHILLINGS.

Printed for the Society
by
A. H. TUCKER, Government Printer, Brisbane.

The Royal Society of Queensland.

Patron:
HIS EXCELLENCY LIEUT.-GENERAL SIR JOHN D. LAVARACK, C.B., C.M.G., D.S.O., C. de G., K.B.E.

OFFICERS, 1951.

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Associate Professor H. J. G. HINES, B.Sc.

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I. M. MACKERRAS, F.R.A.C.P.

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CONTENTS

Vol. LXIII.

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PROCEEDINGS
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ISSUED 17th AUGUST, 1953

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NOTICE TO AUTHORS

1. Each paper should be accompanied by the author's name, degrees and official address.

2. Papers must be complete and in a form suitable for publication when communicated to the Society and should be as concise as possible.

3. Papers must be accompanied by a synopsis prepared according to the direction given on the inside of the back cover.

4. Papers should be in double-spaced typescript on one side of the paper with ample margins.

5. The use of italics in the text should be restricted to generic and specific names, foreign words, and titles of periodicals.

6. The cost of author's corrections to proof above what the Council considers a reasonable amount, must be borne by the author.

7. Unless otherwise specified each author will be supplied with fifty separate copies of his paper. Any number exceeding this may be obtained at approximately cost price.

8. All references should be listed at the end of each paper and arranged alphabetically under authors' names, *e.g.*,

   Keilin, D. (1929). Proc. Roy. Soc. B., **104**, 207.

   Lesage, P. (1895). Ann.Sci. Nat. Bot., **1**, 309.

   The corresponding references in the text should be:

   " Keilin (1929) ", "Lesage (1895) ".

9. The size of the printed plate will not exceed 8 in. x 4½ in., and drawings may be to this size, or preferably to a convenient small multiple thereof. The effect of the necessary reduction on lettering and fine detail should be borne in mind. Text figures should be drawn for reduction to a width not exceeding 4 in.

10. Drawing in line should be executed in intensely black ink such as good India ink, on a smooth surface, preferably Bristol board. Excessively fine, scratchy, or faint lines are to be avoided. Tints or washes cannot be reproduced in line drawings, in which the maximum degree of contrast is necessary.

11. Drawings or photographs for reproduction in half-tone should, where possible, be grouped for reproduction on one plate. They should be done or mounted on a smooth surface, such as Bristol board, as the grain of most drawing papers becomes visible on reproduction. Single photographs should be sent flat and unmounted. All prints should be on glossy bromide or gas-light paper.

Vol. LXIII. No. 1.

Proceedings of the Royal Society of Queensland.

PRESIDENTIAL ADDRESS.

FORM OR FUNCTION.

M. F. Hickey.

(*Delivered before the Royal Society of Queensland*, 2*nd April*, 1951.)

Introduction.

It is a traditional practice in our Society that the retiring President should close the annual meeting with an address or sermon—a task which I find more difficult when I recall (as you undoubtedly will) the addresses of previous Presidents, lingering memories of whose learning and rhetoric may lead you to make odious comparisons.

As my principal work has been as a teacher of Anatomy and as I have for many years been interested in the wider implications of biological and general scientific problems, I hope that you will bear with me if I attempt in this address a two-fold task ; to deal first with some problems inherent in the relationship of anatomy and physiology as University subjects, and secondly to discuss some of the more general problems, verging on or including the philosophical, which arise from a consideration of the relationship between form and function, in both biological and non-biological fields.

Part I.—THE EDUCATIONAL PROBLEM.

The title of my address was chosen, partly because it is sufficiently elastic to allow me some latitude in discussion, and partly because for some time there has been in the biological studies in general a real divorce, and in some cases an antagonism, between these two aspects of a single problem. Especially is this so in human anatomy and human physiology.

(a) The Correlation of Anatomy and Physiology.

Anatomy in general is concerned with structure, and physiology with function. Time does not permit me to record the historical causes of the divorce between these two disciplines ; however, the divorce of the two interdependent aspects of a single subject is a relatively recent one, and is responsible for a considerable wastage of time and effort and loss of student interest in the medical course. It is also responsible for the fact that medical students and others tend to keep their studies of anatomy and physiology in “ water-tight ” compartments. However, the relative neglect of function, both internal and external, is found in biology in general ; and I think that the teachers of zoology and botany in our Universities might well ask themselves how many of the thousands of men and women who have passed through their hands still have a vital and abiding interest in biological inquiry, even as an avocation.

In most medical schools, and this applies particularly in Australia (I don't know what the position is in the veterinary schools, but have no reason for thinking that the situation is any better there), there is little or no correlation between anatomy and physiology. Into the present reasons for this state of affairs, which are not flattering either to the anatomist or to the physiologist, we cannot enter here; but I wish to say a few words about its effects.

The separation of the two subjects is seen in many ways: the competition for working time in the medical curriculum; the lack of co-operation between departments; the tendency—nay, the necessity—for the student to treat the two subjects as completely separate ones, and his failure consequently to develop a "total" view of human structure and function; the real failure to evoke interest in and love for the subjects; the complete absorption of the student's time in his strictly professional studies, with a resulting loss of time, opportunity and inclination for wider education.

If we were to suggest to a mechanical engineer the complete separation of the structural and functional aspects of his subject, he would think we were joking; yet it is a common practice in medical schools not only to have anatomy and physiology taught completely independently from the administrative point of view, but to tolerate a spiritual separation of the departments, a far greater handicap than a merely geographical separation, as is evidenced by the almost complete ignorance of each department of what is being taught in the other, and a lack of synchronization of treatment of material. So bad is this last feature, that the student may be called upon to make a detailed study of function in relation to tissues, organs and organ systems, before he has had the opportunity to acquire the essential knowledge of structure. As a result of this, students find that they are studying for two different examinations, and often studying conflicting views on the same subjects. Any suggestion that this situation should act as a stimulus to the critical powers of the student reveals a complete failure to appreciate the realities of the situation. Assuming even a very high standard of intellectual equipment in the student, this view fails to take account of the fact that, under the present conditions, the student has not the critical equipment either of factual knowledge or of training to enable him to make a judgment between competing views. It is realised of course that there are fields of anatomy of considerable value in clinical work which do not demand excessive physiological treatment, and fields of physiological study the anatomical basis of which is relatively restricted. However, this cannot be considered an impediment to a careful integration of the two fields of study which would involve close co-operation between the departments involved and a continual correlation of the subjects taught.

Evidences of a new attitude to the problem of reconciling the claims of anatomy and physiology are not wanting, and, in this, the attitude is important rather than the details of particular plans. It may interest you to know that an attempt has been made to deal with the problem in the University of Birmingham, where anatomy and physiology have been integrated and a correlated course devised enabling the structure and function of the body to be dealt with as one subject (Zuckerman, 1947).

As T. P. McMurray, Emeritus Professor of Orthopaedics in the University of Liverpool, said (1949):—

> "The idea is excellent; through this arrangement the bald truths of anatomy can be enlightened by the experimental work carried out in the physiological section, and the dead structure of the dissecting rooms can be seen to function in a living medium."

To devise and implement such a plan would, of course, make demands on all the teachers involved for a study of their subject in relation to the whole curriculum, in relation to other subjects, and in relation to the student's needs—rather a novelty in the building of a medical curriculum. For several years, the working out of such a plan has been advocated in our University, and the Faculty of Medicine has approved of the idea in principle. But practically nothing has been done to cope with a situation which, quite frankly, both in the fact of and in the reasons for its existence, is a reproach to our University in this half of the twentieth century. In the other Australian medical schools the situation appears to be quite as bad.

Into the causes of this failure to attempt, let alone achieve, this fusion there is no point in entering here. I would merely say that the fault appears to lie equally with the anatomists and the physiologists, as evidenced in the building of University curricula and in the strictures passed by each group upon the other.

In the medical curriculum there is competition for time-table space between the anatomists and the physiologists, and when the protagonist of one or other of these disciplines fails to secure what he considers to be adequate formal time-table space, he tends to seek, by large reading assignments and the like, to secure it from the student's " free " time. In this competition, the anatomists have tended to be on the defensive and the physiologists on the offensive. Medical teachers and students are from time to time informed by physiologists that " anatomy is relatively unimportant in the medical course, and therefore in medical science and practice." "Anatomy can be taught in a few easy lessons." " Morphology is finished as a research subject."

We may ask ourselves whether there is any truth in these statements, and in their implied corollaries : that physiology is the only subject of importance in medical science and practice ; that physiology needs and deserves much more time than anatomy ; that physiology is the only worthwhile field of research. The claim that morphology is finished as a field of research has two aspects ; one, explicit, that the whole field of morphological investigation has been worked out, a claim that is difficult to reconcile with the great deal of work still being done both in microscopic and gross anatomy, even if we confine our attention to the recent important large scale re-investigations of major problems in surgical anatomy ; the other aspect, implicit, is that the availability of research fields is the most important criterion of the importance of a subject in a medical school, or in a University in general.

This latter notion arises from a misconception of the function of the University teacher and of the functions of a University. Although it is true that the ideal University might be described as a training ground for critical thought, the fact is that this ideal function is an accident of the type of studies undertaken at Universities in the first few centuries of their existence. The Universities began as professional training schools : rightly or wrongly this is also one of their principal characters to-day. From the unfortunate over-emphasis on research as a competitor with, rather than as a stimulus to, teaching stems the fact that appointment to and advancement in University posts goes too much by a reckoning of paper output rather than by educational productivity. There is also the fact that University teachers too often forget that the student must be trained in thinking and in scientific method, and must he helped to enlarge his field of knowledge. This requires time and thought. We should remember that there is an advancing edge to the student's knowledge as well as to that of the research worker ; and in general, both academically and socially, the former is the more important.

Turning to the question of the importance of anatomy, of structure, in the medical course. Assuming that the separation of structural and functional aspects is valid, the suggestion that anatomy is of minor importance in the medical course and therefore, one must suppose, in general practice, is simply a blind perversion of the facts.

It is an inescapable truth that there is no other basis for the study of function and of disturbed function, than a thorough knowledge of relevant structure. As Professor McMurray put it recently (1949) :

> " The student cannot possibly know too much of that subject (Anatomy) : It is just as important for the Doctor to know every part of the human organism as it is for the Engineer to know every nut and bolt of the machine for the repair and maintenance of which he is responsible. The only question then is whether the time spent in anatomical teaching could be rearranged to equip the medical student more fully for his life-work."

A sound knowledge of normal living anatomy is the fundamental basis of the examination of a patient and is essential for a great deal of treatment. There should be no need to labour this point any further ; but relevant questions are, what should be the scope of anatomy, what facts or groups of facts can be omitted from the course, what others could with advantage, be stressed or elaborated ? These questions, of course, might appear meaningless to the pure anatomist to whose mind the subject of anatomy consists of a mass of facts each of which is of equal value. Let us recognise clearly, however, that in medical schools at least, we are training for the practice of medicine and not for a life-long pursuit of anatomy. Into these problems of selection and emphasis of material this is not the occasion, nor is there the time, to enter ; but I should like once again to emphasise the view that so far as the medical student is concerned, one great problem facing the teacher of Anatomy, *qua* teacher, is the problem of method.

(b) Teaching Methods in Anatomy.

I am now going to discuss some problems of technique in anatomical and general morphological instruction. Are there relatively easy and intellectually satisfying methods of teaching structure, and have these been sufficiently exploited ? I think that the answer to the first question is yes, and the answer to the second is a very definite no.

This brings me, then, to the question of teaching technique, mainly in human anatomy. I am not at the moment concerned with how much detailed anatomy should be taught to medical students, for that is not of importance in this discussion, but rather with the consideration of whether present methods of instruction are adequate. Here we may view the matter historically to see how the present situation has arisen. As you know, Physiology and Biochemistry are relatively recent in their full separate development ; and traditionally medical students were concerned with two main activities—dissection of the cadaver, and " walking the wards." A relatively enormous amount of time was allotted to dissection, the body being dissected in detail twice. The student was given a dissecting manual and a cadaver, and set to work on his own voyage of discovery. To a great extent this method still persists ; but even if the time at the student's disposal were unlimited, I should still consider this approach to the subject a very poor one.

Again, as J. D. Bernal (1939, pp. 78-9) has remarked, University curricula have grown by a process of accretion and compression, with very little pruning or attempt at correlation. In the last half century, a whole new field of work in physiology and biochemistry has developed, making more demands on the time and attention of students, but with little accompanying alteration in the scope or method of anatomy.

Are we able to make the approach to dissection one which would produce a much better informed dissector ? The answer, I think, is yes. The first and most important thing to do is, both by ordinary didactic lectures and by demonstration of specimens and of models, to impart to the student a thoroughly sound knowledge of the general architectural problem. In most cases, this involves a complete reversal of the ordinary dissecting room procedure. Instead of working from the skin inwards, we should work from the bones outward, thus preparing the bony skeletal framework in which we are to place muscles, glands, nerves, and vessels. This involves a considerable degree of instruction antecedent to dissection ; but it also means that when the student proceeds to his dissection he does so reasonably well-informed on the general build of the part he approaches. This will ensure that his dissection will be a much better one, much more rapid, and in effect a more detailed revision of the preliminary instruction. It is during this second stage that such details as are considered necessary can be imparted to the student.

It may be objected that by this method too much is done for the student. We could admit the validity of this criticism, if we also admitted that it is not desirable for the student to be a well-informed dissector. What is aimed at in the method suggested is a rapid acquisition of a sound basic knowledge of a region, so that the student may make his dissection of the region a much more profitable one. It has also the great advantage, especially in studying joint mechanisms, one of the most neglected fields in the anatomical training of medical students, of allowing the functional aspect to be dealt with early, thus giving more point to the study of joint and muscle structure.

What accessory devices have we to assist the teaching of structure ? The following may be enumerated—a series of dissections showing the principal masses of a region arranged on a basis of bony structure from within outwards, correlated with the systematic study of cross-sections ; this to be supplemented by special dissections of parts where the details are considered to be of importance in medical practice ; models which can be of enormous assistance in gross anatomy, embryology and histology ; and carefully selected sets of diagrams, x-rays and films.

The use of the above method of approach and of the visual aids suggested, will mean that a student can be put very rapidly in possession of the significant facts of structure as a prelude to or as an accompaniment of the study of function. The result would be considerable saving in time and mental energy. It would ensure a much better dissection and a much sounder knowledge of structure, it would allow greater time for revision, and it would allow a much more knowledgeable approach to the study of normal and disturbed function.

Of course, it may be claimed that technique is easy in theory but difficult in practice ; so I now wish to mention some simple teaching devices, a wider application of which would make the acquisition of knowledge of structure easy and interesting.

[The following part of the lecture was illustrated with lantern slides and films.]

(1) A method for practical histology which aims to help the student to become well-informed on general build before he approaches the problem in detail. One of the great difficulties in large practical classes in microscopic anatomy, especially with junior students, is to ensure that all students have a reasonably clear idea of the appearance of structures for which they are searching. Coloured transparencies of successively greater magnifications photographed directly from class slides can be used to show first the whole mount of tissue, so that the general arrangement can be explained and certain areas pointed out for study; then a low power view of a fairly large segment of a special structure; and in later slides high power views can be shown in which considerable detail can be made out and demonstrated to the student. Other parts of this and other material can be treated in the same way. This method, if properly applied, will make the time needed for the study of pure structure very much less; but it will ensure that the whole class has the opportunity to see what the structure is, and provide more time to make a thorough study of details and so achieve a higher degree of proficiency in the subject. In any rationally planned medical course this will have three advantages: in the first place, it will give a surer structural basis for the study of function; it will give more time for the study of function; and it will provide a sound basis for work in histo-pathology.

(2) A device by no means new, but poorly exploited, is the use of simple models. Home-made models, constructed without great difficulty and in a short time, give the student an incomparably better idea of the general build of the organism or part than do the usual drawings in the textbook, for the three-dimensional qualities can be thoroughly appreciated. Lantern slides made by photographing such models are generally superior to those made by photographing a drawing of a model. Of course, this method applies particularly well in embryology, but it is also very useful in gross anatomy, for by means of a series of simple models, the fundamental architecture of a region can be demonstrated with ease.

[Some home-made models were displayed to give an idea of the usefulness of the material, especially in the teaching of Embryology.]

(3) The third device is the carefully planned application of a well-known technique, the use of ordinary lantern slides in gross anatomy instruction. As a preliminary to the study of a part, the general relationships can be discussed with a large class by means of a careful correlation of cross sections and dissections in flat planes. This can be supplemented by the study of models and of prepared dissections. It is essential that the slides be very clear and not too numerous.

(4) One could continue the enumeration and illustration of these and similar devices, but I will conclude this part of my talk with a few remarks on a technical device of great value in the teaching of living anatomy, the film, silent or with a sound track.

Again, it must be remembered that the film is only a means to the understanding of the actual working body; that there is the danger of the over-use of films, especially excessively long ones; there is the danger, too, of the student playing a purely passive part in the process. These dangers and others are known and can be coped with. Here I wish to say something about the value of films in anatomical teaching.

The films may be roughly divided into four classes :

(*a*) Strip films showing successive stages in a dissection, either as a prelude to, or as a revision of, actual dissection.

(*b*) Films of the animated cartoon type showing embryological development and function.

(*c*) Ordinary films of the living body showing the movement of joints and permitting the analytical study of joint movement, &c.

(*d*) Films showing successive stages in joint movement or in the passage of material through tubular structures as visualised by x-rays.

(*c*) and (*d*) are types which are easily prepared in an Anatomy department equipped with an x-ray apparatus and suitable photographic equipment. I will first show you a film showing the passage of material through a tubular structure : a barium meal passing through the stomach. Then will follow three films to illustrate joint movement in ankle, elbow and forearm.

[Four short films were shown.]

It may interest you to know how such films can be prepared. There are two methods. One is to photograph directly the movements as visualised on the fluoroscopic screen. Technically this is somewhat difficult, but necessary for the study of the movements of tubular structures. The other method, of especial use in the study of joint movement, is to take a series of x-ray pictures in a considerable number of consecutive positions, then photograph these on to a continuous film by using the appropriate number of exposures for each successive position so as to give the illusion of practically continuous movement.

[Illustrated with a series of five lantern slides made from x-ray pictures of five consecutive positions of shoulder joint movement. By increasing considerably the number of intermediate positions there is provided the raw material for a short film, which can be run as an unbroken ring, allowing a complete visualisation of the movement and, in successive stills, a means of analysis of relative angular movement of joint components.]

The advantages of this method are too obvious to need stressing. But here again I cannot too strongly emphasise that this method is only a means to an end—the understanding of the function of the joint in the living body.

I would venture to suggest that somewhat similar devices would be of enormous value in the teaching of physiology and, with due respect, I would also suggest that the carefully prepared film showing some of the routine animal experiments (if indeed these must be used) as a preparation for the actual work by the class would be a very great assistance both to the students and to their instructors. It is a far from uncommon experience to find that the experimental result is nil, due to the imperfect technique of the untrained and ignorant student.

(c) Biology in General.

It will no doubt occur to you that much the same problems of emphasis and method will arise in biology in general. However, both the potential dangers and advantages are greater here, for owing to the fact that both aspects are usually taught in the one department, it may be possible to find biology courses in which there is a careful correlation of structure and function. Nevertheless the very real danger exists that there will be an exclusive emphasis on morphology, with little or no treatment of physiology, ecology and the like, as so wittily and trenchantly stated by William Morton Wheeler (1923); and there is the danger that an excessive preoccupation with physiology proper or with genetics may deprive the student of the opportunity to get to know the animals themselves.

I well remember how after I had graduated in Medicine, I was given a copy of Wigglesworth's small book on "Insect Physiology" by a friend, and how, after a casual glance at the first few pages, I sat down enthralled to read the book through completely. As I went on with the reading, the question kept occurring: why were we not given some similar approach to our study of insects and other animals in our first year of biology? Here was a key to the understanding of structure in terms of function. To what extent function is now being correlated with structure in University courses in biology, I do not know at first hand, but I am inclined to doubt whether nearly enough time and attention is given to the functional illumination of structure as is needed to secure full interest and understanding on the part of the student.

I know, of course, that a certain amount of ecology is now done; a small amount, owing to the difficulties of time-tables. This is important, but is not sufficient in itself; nor does there seem to be enough time and attention devoted to the general functional aspects of the animal types which are studied in the practical classes. This is particularly true of locomotion, a subject easy to study, if not on the living animal, then in films. I feel that this is only partly, and to a minor degree, due to a lack of appreciation of the importance of function, and I am not suggesting that the study of structure be sacrificed to the study of function. Far from it, for we would not wish to have the reproach levelled against zoologists excessively preoccupied with minute physiological and biochemical problems, that the study of animals is unfashionable among them.

It will be apparent that in dealing with the internal correlation of the biological sciences and with the technical problems of teaching in them, we can apply the same principles and have recourse to the same aids as in the teaching of anatomy, and expect to obtain the same advantages. I do not think that there is any need to labour the point.

Probably the divorce of structure and function has never been as marked in general biology as in the medical subjects, unless perhaps in comparative anatomy. Here, however, there are signs of a widening of the scope of the subject, as is evidenced in two outstanding text-books recently published. In his new work on comparative anatomy, Professor Romer (1949) has paid considerable attention to the cognate sciences, including physiology, as well as to essential anatomical or morphological aspects, producing a work which, according to William L. Straus (1950) may play a considerable role in the rehabilitation of this branch of biology. If comparative anatomy is to recover lost ground and prosper, it must become broader in scope; in fact it must become comparative biology, instead of the usual narrow comparative anatomy or morphology; and Romer's book seems to have the necessary qualities.

This approach seems to be even more fully used by Professor J. Z. Young in his recent book (1950) which shows a much needed "holistic" approach to the problem, with structure and function treated together. In fact, his method of treatment "challenges the appropriateness of the conventional distinction between the two subjects." He deals with the whole working organism, and provides not simply a functional morphology nor a physiology with an anatomical substratum. Professor Young's expressed intention is to treat of the life of vertebrate animals in its most complete synoptic sense, its origin and secular changes of complexity, the means by which animals cope with the hazards and contingencies of living and staying alive, the varieties of truce that accommodate the chronic enmity of the environment, and everything else that is entailed by the act of living. " The central fact of biology " says the author, " is that life goes on."

(D) SOME GENERAL CONSIDERATIONS.

If the example of the University of Birmingham in anatomy and physiology is more widely tried out, and if the attitude of Romer and Young becomes more generally adopted, we may have some hope that the leaven will spread rapidly amongst University teachers and have some influence on the anatomists and the physiologists, so that both may come to realise that they are guiding students, and not teaching subjects. It may even come about that medical faculties and their committees charged with the construction of curricula, may give some considerable degree of attention to this fundamental problem of correlation. We realise, of course, that this may make serious demands on the egoism of both anatomists and physiologists. It may also mean that each will have in some way or other to keep themselves ' au fait ' with what is going on in each other's fields of work. It may mean even more that some serious attention will be given to the scientific approach to the problems of curriculum structure and of teaching.

I make no apology for having spoken at some length on the problems of correlation of subjects and teaching techniques. We have too long had an excessive tenderness for professors and lecturers whose main qualifications have been the passing of examinations and the writing of papers. Let me make it clear that I am not denying the importance of research work, but I do consider that we should see it in its proper perspective. Whether we like it or not, in medicine, dentistry, veterinary science and applied biology, we are concerned with training students for professional careers in which a working knowledge of the subject is of great importance for the performance of everyday professional tasks. This preparation is both historically and sociologically a University work.

It may be claimed, and often it is, that if we set about devising curricula on a planned system, and if we look for newer and easier methods by which the student may master the material essential for his professional work, we are " spoon-feeding " him, that we are getting away from the true spirit of the University, and that we will destroy his initiative. Is there any substance in this criticism ? Frankly, I think not.

If we are able to devise better methods of instruction, especially on the basic principles of a subject, we can make much heavier demands on the student in terms of performance. Let us look at it in this way. If we are instructing students in anatomy, including histology, as a preparation for their study of physiology, then surely in all common sense we should teach as much as is possible of the common ground of structure and function in the one course. Further, the devising of techniques of instruction, which will make as easy as possible the acquisition of a thoroughly sound knowledge of structure, will not only make the student more interested in his subject, due to his more rapid appreciation of it, but also will give him much better intellectual equipment and much more freedom of time and mental energy for the study of function, which many physiologists will tell us is of overwhelming importance. It may give the student some free time in which he can be encouraged to study the history and structure of the society in which he is to do his life's work, to become acquainted with some at least of the literary and artistic life of the world.

We must not lose sight of the fact that all of these devices are merely a means to an end, to a knowledge of the build and working of the living body; but the means are of great importance not only in this particular field, but in the wider fields of education.

A consideration of methods is only part of a scientific approach to the problems of teaching, and teaching is teaching whether in a University or in a secondary school. It has problems of technique as well as content and correlation. The importance of a high standard of skill in University teachers as such is now being stressed in widely diverse quarters. For example the former Vice-Chancellor of the University of Melbourne, Sir John Medley (1950) leaves no doubt about his views :—

> " I feel sure that of late years we—and I speak now of University theorists in general—have tended unduly to exalt research at the expense of teaching, and that the true picture of a University's function has been blurred thereby. . . And yet to hear some of the extremists talk you would come to the conclusion that teaching was nothing but an unfortunate but inevitable excrescence upon the body academic, and that nobody should be appointed to a University staff unless his research record was of first rate calibre. . . . . The teacher is the backbone of any true University, and there will always be teachers of first rate capacity whose talents do not lie in the direction of original work and will be sadly wasted if pressure of academic opinion forces them to devote time to so-called research that could be better spent in their proper job."

Do not imagine, however, that Sir John regards research as of no account; far from it, as a perusal of his whole address will make clear.

Now Sir John Medley is an administrator, and perhaps you may think that his views are prejudiced in favour of administration and teaching. Let me quote to you the words of one of the leading researchers of our time, Sir Macfarlane Burnet (1948), who, in discussing the relation between teaching and research in the University, writes as follows :—

> " There is a widely current attitude that the only activity of a professor which matters is his research work: teaching and administration are time-wasting obstacles which are necessary but unfortunate concomitants of the appointment."
>
> " This seems to be a highly unhealthy condition, which, like most things human, does not work out quite so badly as it ought to. It is a rather naive and socially untenable attitude to assume that part-time research, which, because it is part-time, must in most instances be of relatively unimportant character, is to be regarded as of greater importance than effective teaching. Good education, with which must be included proper selection of those fitted to benefit by it, is the most important requirement for the production of medical men and scientists. The effective organization of a University department, so that it can fulfil all its functions of teaching, research and outside advice, is a full-time job that is more important than any but the rarest of advances in research."
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> " This may seem a highly heretical statement worthy only of those who regard a university simply as a school for higher vocational training; but as one who can hardly be accused of ignorance about the values of fundamental research, I feel strongly that it should be seriously considered by anyone concerned with attempts to remedy the present difficulties of Australian universities."

Professor Burnet then outlines the ideal structure of a University department in one of the Sciences.

> " The head of the department would have final responsibility for all its activities but would spend no significant proportion of his time on personal bench investigations. The professor's primary interest would be in effective teaching, using this in the broadest sense, and in the organisation of his department to provide this more and more efficiently. His activities at the research level would be essentially research into teaching methods, the devising of visual aids, improvement in laboratory training, the assessing of capacity for specialised work in students: in other words, educational research applied to the teaching of his science."

I should like to quote this article at greater length, but time permits no greater quotation than I have so far made.

Part II.—THE PHILOSOPHICAL AND ETHICAL PROBLEMS.

(A) In Biology.

With your indulgence I now propose to deal briefly with some general problems that arise in biology concerning the meaning of the relation of living function to living structure and the relation of both of these to a wider scheme of things. For example, it is held by some, and denied by others, that some aspects of modern biology have been destructive of ethics.

It has been suggested, for example, that the insistence on the struggle for survival and on the survival of the fittest in nature has made it difficult for us to believe in the possibility of finding a worthwhile ethical system; and that this is due to the work of men such as T. H. Huxley. This belief has arisen from a misconception or a plain misrepresentation of 19th century biology.

One of those who declare, and presumably believe, that Tennyson's phrase of "Nature red in tooth and claw" was adopted by the immediate exponents of Darwinism, is that distinguished anatomist, Professor Wood Jones; and in a recent book (Wood Jones, 1942) he sets out to propound that biology everywhere shows evidence of design and of purpose; and incidentally, that the struggle for survival is *not* the keynote of the world of nature, but that mutual aid and mutual support are the fundamental characteristics of nature.

It is not possible here to deal in detail with this thesis, but I think it is proper that certain aspects should be mentioned. Wood Jones rightly points out that Darwin realised there was mutual dependence, as well as competition, everywhere in nature. However, he goes on to say (p. 45):—

> "The pictures of relentless competition, of bloody strife, and ultimate elimination of the weak in favour of the strong made great appeal to Huxley in England and to Haeckel in Germany, and by them they were handed on to a receptive public incapable of estimating their true value."

I think that Wood Jones is right in stressing the implication of dependence of living things upon each other, as did Kropotkin (1902, 1919); but I think he is in error in declaring simply that "nature is a series of harmonies in which living things play mutually dependent parts," and that increasing population does not produce inevitably and fundamentally a competition for survival, the struggle for existence, both within groups and between groups. He must be blind to what is going on in the world about him, both human and non-human.

However, I am not concerned here to support this theory of the struggle for existence in Nature, but to draw attention to and deplore Wood Jones' implicit misinterpretation of T. H. Huxley; for he would leave us with the idea that Huxley believed and taught that the struggle for survival should be the keynote of the human situation, that it was the teaching of Huxley and his school which was responsible in great part for the present chaos in theological and ethical beliefs.

The fact of the matter is that Darwin never suggested that we should transfer the operations of the rest of the animal kingdom to the field of human conduct; and indeed it was T. H. Huxley (1895) who emphasised most strongly that the cosmic process in nature must be subdued to the ethical process. Let me quote from Huxley himself (pp. 80-83) :—

> " There is another fallacy which appears to me to pervade the so-called ' ethics of evolution.' It is the notion that because, on the whole, animals and plants have advanced in perfection of organisation by means of the struggle for existence and the consequent ' survival of the fittest ' ; therefore men in society, men as ethical beings, must look to the same process to help them towards perfection. I suspect that this fallacy has arisen out of the unfortunate ambiguity of the phrase ' survival of the fittest.' ' Fittest ' has a connotation of ' best ' ; and about ' best ' there hangs a moral flavour. In cosmic nature, however, what is ' fittest ' depends upon the conditions. "
>
> " Men in Society are undoubtedly subject to the cosmic process. As among other animals, multiplication goes on without cessation, and involves severe competition for the means of support. The struggle for existence tends to eliminate those less fitted to adapt themselves to the circumstances of their existence. The strongest, the most self-assertive, tend to tread down the weaker. But the influence of the cosmic process on the evolution of society is the greater the more rudimentary its civilisation. Social progress means a checking of the cosmic process at every step and the substitution for it of another, which may be called the ethical process ; the end of which is not the survival of those who may happen to be the fittest, in respect of the whole of the conditions which obtain, but of those who are ethically the best."
>
> " As I have already urged, the practice of that which is ethically best—what we call goodness or virtue—involves a course of conduct which, in all respects, is opposed to that which leads to success in the cosmic struggle for existence. In place of ruthless self-assertion it demands self-restraint ; in place of thrusting aside, or treading down all competitors, it requires that the individual shall not merely respect, but shall help his fellows ; its influence is directed, not so much to the survival of the fittest, as to the fitting of as many as possible to survive. It repudiates the gladiatorial theory of existence. It demands that each man who enters into the enjoyment of the advantages of a polity shall be mindful of his debt to those who have laboriously constructed it ; and shall take heed that no act of his weakens the fabric in which he has been permitted to live. Laws and moral precepts are directed to the end of curbing the cosmic process and reminding the individual of his duty to the community, to the protection and influence of which he owes, if not existence itself, at least the life of something better than a brutal savage."
>
> " It is from neglect of these plain considerations that the fanatical individualism of our time attempts to apply the analogy of cosmic nature to society . . . . "
>
> " Let us understand, once for all, that the ethical progress of society depends, not on imitating the cosmic process, still less in running away from it, but in combating it."

One would think that there could scarcely be a plainer statement of the contrast between the ethical and cosmic processes ; you have your choice of reading Huxley's ideas in his own words or Wood Jones' prejudiced mis-statement of those ideas.

However, Huxley realised quite well that human affairs show a struggle between our cosmic and our ethical nature, one that will be as long lasting as human life, but one in which will and intelligence will help the ethical process to curb the cosmic, although with difficulty (p. 85) :—

> " Moreover, the cosmic nature born with us, and to a large extent necessary for our maintenance, is the outcome of millions of years of severe training, and it would be folly to imagine that a few centuries will suffice to subdue its masterfulness to purely ethical ends. Ethical nature may count upon having to reckon with a tenacious and powerful enemy as long as the world lasts. But on the other hand, I see no limit to the extent to which intelligence and will, guided by sound principles of investigation, and organised in common effort, may modify the conditions of existence, for a period longer than that now covered by history. And much may be done to change the nature of man himself. The intelligence which has converted the brother of the wolf into the faithful guardian of the flock ought to be able to do something towards curbing the instincts of savagery in civilised men."

If I have quoted rather fully from Huxley, it is because it seems necessary to make clear once again what Huxley did say, especially in these times when too many prominent publicists, theological and otherwise, blame the moral ills of the world on " science " or " Darwinism," or " scientific materialism," in many cases without knowing what the scientists concerned have said, and in some cases quite obviously misrepresenting their views.

It should be clear from the paragraphs quoted that Huxley's view of the ethical process as supplanting the cosmic process has implicit in it the notion of interdependence ; indeed the ethical process can develop only with an increasing recognition of this interdependence. Huxley's own words are explicit—" Let us understand once for all that the ethical progress of Society depends, not on imitating the cosmic process, still less in running away from it, but in combating it."

Another charge against 19th and 20th century biology is that it has destroyed the " comfortable " assurance of an all-pervading design and purpose in nature, with deleterious effects on ethics. Into the question of whether there is purposiveness in nature, in evolution, and in human life, we cannot enter at length here. There is no doubt about the views of some of the leading biologists to-day on this matter. Alfred Romer (1949), a leading American comparative anatomist and palaeontologist, sums up modern views when he says that there is no evidence of design or direction in evolutionary changes. Rather, the changes are due to mutations ; the process of mutation seems to be merely one of blind random change ; but, he says, " Vertebrate evolution certainly appears to be a process which has resulted in changes both useful and adaptive. How can such results have come out of the mutation process " ? In short, he summarises modern views thus (p. 14) :—

> " Both observation and experiment indicate that even small mutations in an adaptive direction have a distinct survival value, and may become dominant in a species in a short time. This natural selection of such a random series of mutations as have adaptive value would appear to be a major mechanism of evolutionary change."

The question is discussed by Julian Huxley in his " Evolution : the Modern Synthesis " (1942), and so well discussed (pp. 576-8) that I will quote rather fully :

> " The ordinary man, or at least the ordinary poet, philosopher, and theologian, is always asking himself what is the purpose of human life, and is anxious to discover some extraneous purpose to which he and humanity may conform. Some find such a purpose exhibited directly in revealed religion ; others think that they can uncover it from the facts of nature. One of the commonest methods of this form of natural religion is to point to evolution as manifesting such a purpose. The history of life, it is asserted, manifests guidance on the part of some external power ; and the usual deduction is that we can safely trust that same power for further guidance in the future."
>
> " I believe this reasoning to be wholly false. The purpose manifested in evolution, whether in adaptation, specialization, or biological progress, is only an apparent purpose. It is just as much a product of blind forces as is the falling of a stone to earth or the ebb and flow of the tides. It is we who have read purpose into evolution, as earlier men projected will and emotion into inorganic phenomena like storm or earthquake. If we wish to work towards a purpose for the future of man, we must formulate that purpose ourselves. Purposes in life are made, not found. . . . ."
>
> "Human purpose and the progress based upon it must accordingly be formulated in terms of human values ; but it must also take account of human needs and limitations, whether these be of a biological order, such as our dietary requirements or our mode of reproduction, or of a human order, such as our intellectual limitations or our inevitable subjection to emotional conflict.. . . . ."

> "But let us not forget that it is possible for progress to be achieved. After the disillusionment of the early twentieth century it has become as fashionable to deny the existence of progress and to brand the idea of it as a human illusion, as it was fashionable in the optimism of the nineteenth century to proclaim not only its existence but its inevitability. The truth is between the two extremes. Progress is a major fact of past evolution; but it is limited to a few selected stocks. It may continue in the future but it is not inevitable; man, by now become the trustee of evolution, must work and plan if he is to achieve future progress for himself and so for life."
>
> "This limited and contingent progress is very different from the *deus ex machina* of nineteenth-century thought, and our optimism may well be tempered by reflection on the difficulties to be overcome. None the less, the demonstration of the existence of a general trend which can legitimately be called progress, and the definition of its limitations, will remain as a fundamental contribution of evolutionary biology to human thought."

One of the great problems of the relations of structure and function is that involved in the elucidation of the methods of evolution, that is the relation of the varied modifications which structures have undergone and the accompanying functional changes. As Romer (1949) points out, "Most structural and functional changes in the vertebrate body are quite clearly adaptive modifications to a variety of environments and modes of life." This would be accepted both by neo-Darwinians and their opponents —omitting, of course, those who deny an evolutionary process. But how these adaptations have been brought about is a matter on which there have been, and are, several theories. These theories are briefly :—

(1) The naive suggestion of adaptation changes occurring as if the animal "willed" them, or as if its needs or desires in themselves brought new structures or structural changes into being.

(2) These theories are not far removed from some "philosophical" theories of evolution which have had, and still have a certain vogue. Theories of orthogenesis assume that there is some mysterious "inner urge" or "inherent tendency" within the organism which brings about these changes; then there is the theory that evolutionary changes are the result of the "design" of some supernatural force. Since such theories are non-scientific, they cannot be scientifically disproved; but we are at liberty to look for more reasonable explanations of evolution based on known facts.

(3) A more plausible attempt at interpretation of structural evolutionary changes was that first advocated over a century ago by Lamarck—a belief that characters acquired through the effects of the environment or of use and disuse could be transmitted to subsequent generations. As if one might say: "If the giraffes' ancestors stretched their necks for foliage on high branches, the effects of this stretching would be transmitted to their offspring, generation after generation, and an elongate neck gradually developed in the hereditary pattern." Or again: "If the snakes' lizard ancestors ceased to use their legs in locomotion, the cumulative result of disuse would be that of eventual loss of the limbs." This attractive theory seems simple, reasonable and natural; but its present standing is very poor indeed.

(4) There is finally the neo-Darwinian view that the major mechanism of evolutionary change is the operation of the natural selection of such a random series of mutations as have adaptive value.

However, this last theory is not accepted universally. You are probably well aware that in Soviet Russia it is laid down politically as well as scientifically, that the environment is the principal modifying factor in evolutionary changes. Into the merits of this belief it is impossible to enter here, but we are entitled to say that the well-substantiated persecution of Mendelian geneticists in Russia has raised the controversy far above the level of a scientific dispute, and I think we are also entitled to ask what is the motive behind the crisis in Soviet biology. It has been suggested by Darlington (1947) that a government which relied on the absence of inborn class and race differentials in man as the basis of its political theory was naturally unhappy about a science of genetics which relies on the presence of such differences amongst plants and animals as the basis of evolution and of crop and stock improvement : it was desirable to have a theory of genetics interpreted and controlled by Moscow.

But the advocacy of Lamarckism is not confined to Lysenko and his political backers. Fairly recently Wood Jones in " Habit and Heritage " (1943) sets out to re-establish Lamarckism, or, the transmissibility of somatic modifications or acquired characters, i.e. " features developed during the life of the individual possessing it in response to the action of use or environment." Into the validity of Wood Jones' thesis it is not possible or necessary to go at this juncture. There are however, two points on which I should like to comment. The first is his attitude to modern genetics as is shown in the conclusion of his book, where derisively but with felicitous style he likens the geneticist to the Chinese cashier manipulating his abacus. He says (p. 99) :

> " I have, at times, been tempted to wonder if my unbounded admiration for the facility with which the modern geneticist solves his problems, by manipulating hypothetical little balls—called genes—along the bars of the chromosomes, may be in part due to my astonishment at his dexterity and to my mystification concerning the niceties of the working of his instrument. We have now a whole race of scientists trained in the refined use of the abacus of heredity. Their manipulation of the little balls of destiny has become an occupation demanding extraordinary skill and a deal of specialized knowledge and literature. Beyond any doubt they possess an instrument and a technique that enables them to keep tally of the petty cash transactions of heredity. It is doubtless a mere impertinence on the part of one who is not a professed, nor even an initiated, geneticist to wonder at times if the great reliance placed upon the workings of the abacus of heredity is not perhaps repressing the development of a possible higher mathematics of inheritance. For undoubtedly there is a higher sphere of inheritance and it must be sought, not through a microscope, not even by the most nicely adjusted experiments, carried on for a short time in the short life of one human being, but by a survey, incomplete though it must necessarily be, of what Nature, with time unlimited at its disposal, has effected among living things."
>
> " We may be running the risk of becoming blind to the whole range of the possibilities of inheritance, if we concentrate too exclusively on the minutiae of the means and modes by which in certain cases, it appears to be effected."

Those of us who know something of the work of the modern geneticist can assess this passage at its real value. We see in it many of the devices of the advocate, not of the disinterested seeker after truth. We observe, for example, the false modesty (" my unbounded admiration " ; " a mere impertinence on (my) part ") ; the pretence that here is a field of work into which the writer is not qualified to enter (" my astonishment " ; " my mystification," etc.) ; the mild derogation ("petty cash transactions ") ; the implied untruth that geneticists are unaware of the necessity of studying the " higher sphere of inheritance " because they " concentrate too exclusively on the minutiae," etc. One could go on to point out the falseness of the analogy of the geneticist with the abacus worker, the fact that many first rate geneticists are also very keen naturalists and general biologists, that the study of variation and genetics goes hand in hand with the study of the causation of variation. But to do so would be a little pointless ; we need not expand this analysis, for the explanation of Wood Jones' views is to be found not in what he wishes to establish as scientific truth but in what is his purpose in writing the small book from which the quoted paragraphs are taken.

Wood Jones would have us believe that he prefers to be uninformed of the whole field of modern morphological and physiological work in genetics, so that he may cling to certain beliefs which he hopes are true. He seems to have allowed his scientific attitude to be clouded over with an adherence to certain philosophical principles, for in his first chapter he suggests that what he calls " the breakdown of ethical standards " is due in some degree to the widespread acceptance of the Darwinian " struggle for existence," and rejection of the idea that acquired characteristics can be transmitted, for he writes (p. 11) :

> " Has not science—even in the most considered and orthodox pronouncements of its most distinguished exponents—possibly led humanity astray in the matter of responsibility in heredity ? There was a time when people believed that the sins of the fathers were visited on the children. This belief was incorporated into the teaching that the parents need have some care of their ways of life, lest their acquired shortcomings and moral lapses might be perpetuated in their descendants. It led also to a general belief in the possible ultimate betterment of mankind by a raising of the standard of parental mode of life and well-being. Such hopes have been dashed to the ground. Loud-voiced Science has told the people that characters acquired by individuals can under no circumstances be transmitted to their descendants. It matters not if we live good lives or bad, for, apart from direct disease or social degradation, we cannot hand on to our descendants any vices, any talents or degeneracies that we may have acquired during our lifetime."

While we cannot quarrel with Wood Jones in his desire to find some way to improve ethical standards, I think that we are justified in pointing out how in this last quoted passage, he makes certain assumptions which it would be extremely difficult to prove. As we know, the neo-Darwinian theory is that evolutionary changes are due to adaptive selection of chance variations due to mutations of genes ; and, further, Lamarckism, both in its original form and in Wood Jones' version of it, is dealing with somatic characters. Now, even if we assume the validity of the Lamarckian proposition, are we going to assume that because some modifications can be transmitted, ethical modifications can be likewise transmitted ? It appears to me that here Wood Jones is guilty of a deliberate confusion of terms ; it does matter if we lead good lives or bad, not because we can hand on our virtues and vices by heredity, but because man is a social animal, and by living good lives we create an environment in which other good lives can be lived. A sound ethical system is a social inheritance, and not an individual somatic one.

That science may be related to ethics, and that the acceptance of the orthodox biological theories is not incompatible with an attempt to devise ethical systems, is shown in the address of a few months ago by Dr. Barnes, Bishop of Birmingham (1950). Many of us who would agree with Dr. Barnes' ethical judgments would not agree with his theology. However, that need not be a disturbing thought, for, as Leonard Huxley has written (1920, p. 80) :—

> " It is alike interesting and satisfactory to reflect that practical morality in civilized life is much the same for all earnest men, however they differ in their theories as to the origin of moral ideas and the kind of motives and sanctions to be insisted on for right action. It is true that the theologians and supernaturalists have erected their scaffolding around the building of social and human anatomy, vowing that it will not stand without. Yet it remains steady when the scaffolding is warped by the winds of doctrine or uprooted by advancing knowledge."

(B) IN PHYSICS.

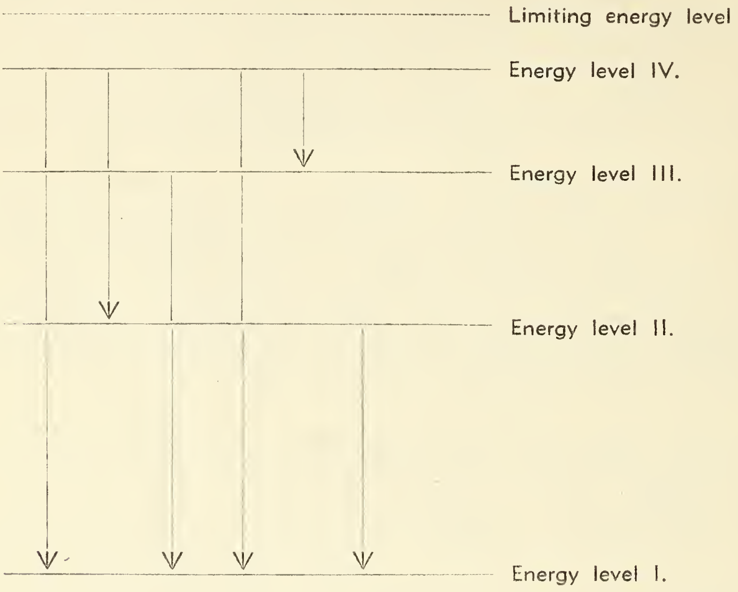
The question of the relation of form and function is of interest and importance in many fields other than the zoological—in botany, in geography, in chemistry and physics. I have no doubt that all of you will have realised this fully long ago. And now, having dealt at some length with some more or less philosophical aspects of biology, I will beg your indulgence for a few minutes longer, whilst I venture, in the words of Seneca, "in aliena castra transire, non tanquam transfuga sed tanquam explorator."

With some trepidation, I propose to say a few words about the philosophical implications of modern views of the form and function of matter. The field of physics is particularly interesting, for here we find that in the realm of micro-physics, i.e. intimate atomic "structure," the physicist tells us that structure disappears in function, and mass has come to be viewed as a form of energy ; and where previously we might have the comfortable assurance that we could build a model of the atom, we now find that we are not justified in such a procedure.

As you know, the Rutherford-Bohr atom succeeded the era of the 92 elements, each with its own sort of atom. In this new atom the picture was simplified. Bohr's theory of the structure of the atom was based upon Rutherford's conception of the atom as consisting of a small positive charge of electricity (the nucleus) surrounded by a number of electrons. Each atom could be regarded as a system composed of only two kinds of constituents—electrons and protons. The electron has a negative charge of electricity, the proton an equal positive charge ; the proton has about 1,850 times the mass of an electron. The nucleus is composed of a number of protons and a smaller number of electrons. The nucleus is regarded as taking the position of the sun, with electrons as planets revolving around it, the number of planetary electrons being just sufficient to make the total number of electrons (nuclear and non-nuclear) equal to the total number of protons. Bohr assumed that the orbits were circular ; they were later shown to be elliptical.

This atom had for a while a great success, as it explained many observed facts almost perfectly. But after a reign of about twelve years it was deposed in the mid-twenties in favour of the Heisenberg-Schrödinger atom, which was a much more abstract and less imaginable affair. It is still permissible to talk about electrons and protons just as we talk of sunrises and sunsets in spite of Copernicus ; but the ultimate truth is supposed to be something quite different. New kinds of units—neutrons, positrons, mesons and so on have been added, with such complexity of function that it appears to be impossible to describe a model even as an extreme concession to our desire for an imaginative picture of physical processes.

Now, Bohr's atom was soon seen to present difficulties to classical physics, according to which the energy of the atom ought gradually to decrease, with the electron consequently assuming an orbit of ever decreasing radius ; but such was not the case, for it seemed that there were only certain admissible orbits and that while an electron, when it emits or absorbs energy, can be said to "jump" from one orbit or energy level to another, there can be no "jump" from an intermediate position. These admissible orbits are those which possess angular momentum an integral multiple of $\frac{\mathbf{h}}{2\pi}$, **h** being Planck's constant. "Jumps" may be "up" or "down," but only from the shown levels. Susan Stebbing (1944, p. 133) illustrates the point by means of a diagram like this:—



The radical departure from classical physics can be illustrated from radioactivity. Statistically we know in radioactivity just how many atoms will decay, but we cannot give anything more than the probability for any individual atom. The initial state does not " determine " the final state in an individual case ; hence the final state is unpredictable. It is unfortunate that this unpredictability has often been expressed by saying that the electron is " free to choose " where it will jump. Such language is wholly inappropriate and has led to much confusion in discussions concerning the bearings of recent developments in physics upon the problem of free will.

Put briefly, the problem is this—since every physical entity must be measurable, how is the position or the velocity of an electron to be measured ? However, the means of measurement in this case affect the phenomenon being investigated, so that in the case of an individual electron it is not possible to ascertain with complete accuracy both the momentum and the position of an electron : the more accurately the one is ascertained, the more inaccurately is the other ascertained. The " more " is formulated in Heisenberg's " Principle of Uncertainty," which states that the product of the uncertainty of position and the uncertainty of momentum is never less than Planck's constant **h**, i.e. there is a theoretical limit to the accuracy with which the state of a material system can be investigated.

Consequently it is not possible, even in principle, to know the initial conditions in the case of quantum phenomena. The classical deterministic system was based upon the assumption that the initial conditions can be precisely known—which is true of macroscopic phenomena ; but no completely accurate predictions, except statistical, are theoretically possible in the case of micro-physical systems.

The effects of this new concept on popular philosophy have been well summarised by Crammer (ed.) (1950) :—

> " When in 1926 Heisenberg contributed his principle of Indeterminacy to the development of the theory of quantum physics, a new era opened in popular philosophy. What was intended to be a specialised theoretical contribution to a restricted field of physics was quickly twisted by certain popularisers of science and by delighted clergymen into meaning the general overthrow of the laws of causality. The nineteenth century view of the Universe as a great machine was suddenly seen to be hazy in fine detail ; there was still room for human free will, for miracles and the intervention of the hand of God ; for once, modern science had been compelled to grant living space to religion—thus ran the new popular philosophy. It was a philosophy based on a misunderstanding at its scientific root. Heisenberg had been concerned to point out that we cannot by the nature of our methods measure simultaneously both the velocity and the position of an atomic particle ; thereby stimulating closer scientific inquiry of methodology in physics. But he said nothing about the behaviour of particles being causeless ; this was added by the popularisers."

However, to many it seemed that there was now a way of escape from the nineteenth century nightmare of rigid determinism of all activity, including mental activity and ethical judgment; i.e., the way was open for some freedom of the will ; " mind " was restored to supremacy, material objects could be regarded as " abstraction," and " materialism " was supplanted by " idealism " ; " mind " could be regarded as the creator.

What is the real situation ? Do the uncertain relations show that there is anything indeterminate in Nature, or that science has now had to become inaccurate ? Bertrand Russell (1946, p. 15) puts it simply :—

> " There are rules governing the changes that atoms undergo from one energy-level to another, but these rules are not sufficient to determine which of several possible things an individual atom will do. They do, however, suffice to determine the average behaviour of a large number of atoms. The case is analagous to throwing dice. . . . . . given a very great many atoms, all capable of a certain definite set of transitions, we can tell, almost exactly, what proportion will " choose " each possibility, though we cannot tell which will be chosen by any particular atom. Consequently the behaviour of matter in bulk is statistically deterministic, although each separate atom may make any one of a certain definite set of transitions."

Given that an experiment is repeated a great many times, then it is possible to predict both the frequency of occurrence of the expected effects and the deviation from these effects. There is nothing lawless in quantum phenomena.

And on the question of whether physics is still deterministic, Russell writes (p. 16) :—

> " The failure of determinism, where atomic occurrences are concerned, has much less importance than is sometimes attributed to it. Except in a well-equipped physical laboratory nothing can be discovered about the behaviour of an individual atom or electron ; all the occurrences of which we are aware in ordinary life involve many millions of atoms and are therefore just as predictable as they used to be. It is true that the prediction is now only probable, but the probability is so near to certainty that the element of doubt due to this cause is very much less than that which will always be present owing to other causes. . . For practical purposes, therefore, physics is still deterministic, the only change is that the deterministic laws are all statistical."

A further comment may be made. Although it is true that if the rigid determinism of classical physics applied to human actions, these would be completely unfree, still, as Susan Stebbing points out (1944, p. 161), " it cannot be maintained that all that is required for human freedom is some amount of uncertainty in the domain of microphysics." Can we really say that—" physical events are not pre-determined, so that it follows that human actions are not predetermined." If we can say this, we are confronted by "the difficulty of the ridiculously small amount of indeterminacy that the measure of the uncertainty relations involves. There is an appreciable degree of indeterminacy only in the case of electrons and atoms; human beings are polyatomic; human actions take place in the world of macroscopic bodies." (p. 152).

Further, there is an immense cleavage between the behaviour of inorganic bodies and the behaviour of a human being—for the latter is able to tamper with the odds on atomic behaviour. This cleavage may not do violence to physics, but it seems to leave the problem of free will just where it was before physicists became indeterminists.

To my mind there is an insuperable difficulty to the transference of quantum indeterminacy to human freedom of the will.

If there is a primary casualness in microphysics, when we transfer this to the field of human action, surely we can only expect casual "ethical" judgments—complete unpredictable caprice—which has nothing to do with the character of the individual, that is, the very reverse of ethics.

We have already seen how Wood Jones has allowed his attitude to genetics to be distorted by his views on the causation of the breakdown in ethical standards; and Susan Stebbing (1944, p. 166) has remarked on how various thinkers have reacted to the contemporary situation in physics each in conformity with his own philosophy of life :—

> "Planck is anxious to refute indeterminacy in physics in order to save the dignity of man. Eddington is anxious to increase the amount of indeterminacy, recently introduced into physics, in order to safeguard our feeling of responsibility. Sir Herbert Samuel is afraid lest the denial of determinism should make man the sport of chance and lead to irresponsibility in action and increase of unreason in politics and life."

As I see it, the problem of "the freedom of the will" is, sociologically at any rate, a false problem. The assumption of the reign of law is that the law can be known, that the individual, unless disabled through infancy or senility, disease or toxic substances, etc., is able to make a choice between actions which we label "good" and "bad." If we do not accept this assumption, we must agree that responsibility is an illusion; if we do accept it, we have two alternatives—either we must hold that physics can be reconciled with the fact of responsibility and show how it can be reconciled; or we must agree that no reconciliation is required because there is no conflict—this last is the practical solution so far accepted by human society.

The false philosophical and ethical deductions from modern physics are only part of a general picture of the "retreat from reason" of which we see so many evidences to-day—man is being asked to save himself by the acceptance of unreason, So well has the situation been expressed by Susan Stebbing that I will close my address by quoting from the last paragraph of her "Philosophy and the Physicists" (1944, p. 212) :—

> "Is it not odd that men should come to this pass—that they look for hope in physics and welcome, as some do, any indication of unreason in the world? Perhaps it seems less odd when we reflect upon the history of mankind, the hopeless mess that we have made of human lives. Our greed, our stupidity and lack of imagination, our apathy, these are the factors upon which the present sorry state of the world is largely consequent. It is enough to fill us with despair. Yet, despair need not be the last word. It lies within our power, if we so desire, to make the familiar world we inhabit more worthy of habitation by beings who aspire to be rational and are capable of love. Our limitation is due not to ignorance, not to the 'blind forces of Nature,' not to the astronomical insignificance of our planet, but to the feebleness of our desires for good. This limitation is not to be removed by the advance of physical knowledge, nor should our hopes be placed in the researches of the physicist."

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Vol. LXIII. No. 2.

STUDIES OF THE LIFE HISTORIES OF SOME QUEENSLAND BLATTIDAE (ORTHOPTERA).

Part 1. The Domestic Species.

By Pauline Pope, Queensland Institute of Medical Research.

(With 9 Text-figures.)

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INTRODUCTION.

Interest in Blattidae was aroused by finding two species naturally infected with Salmonella during an epidemic of gastro-enteritis in Brisbane in 1947 (Mackerras and Mackerras, 1948), and subsequently demonstrating that artificially infected cockroaches might remain carriers for six weeks (Mackerras and Pope, 1948). It was then realised that, although many studies of domestic blattids have been made in other parts of the world, we could find no comprehensive account of any species in Australia. Answers to the questions " How long do egg-capsules take to hatch ? ", and " How long may adults live ? " were necessary in planning a campaign of control.

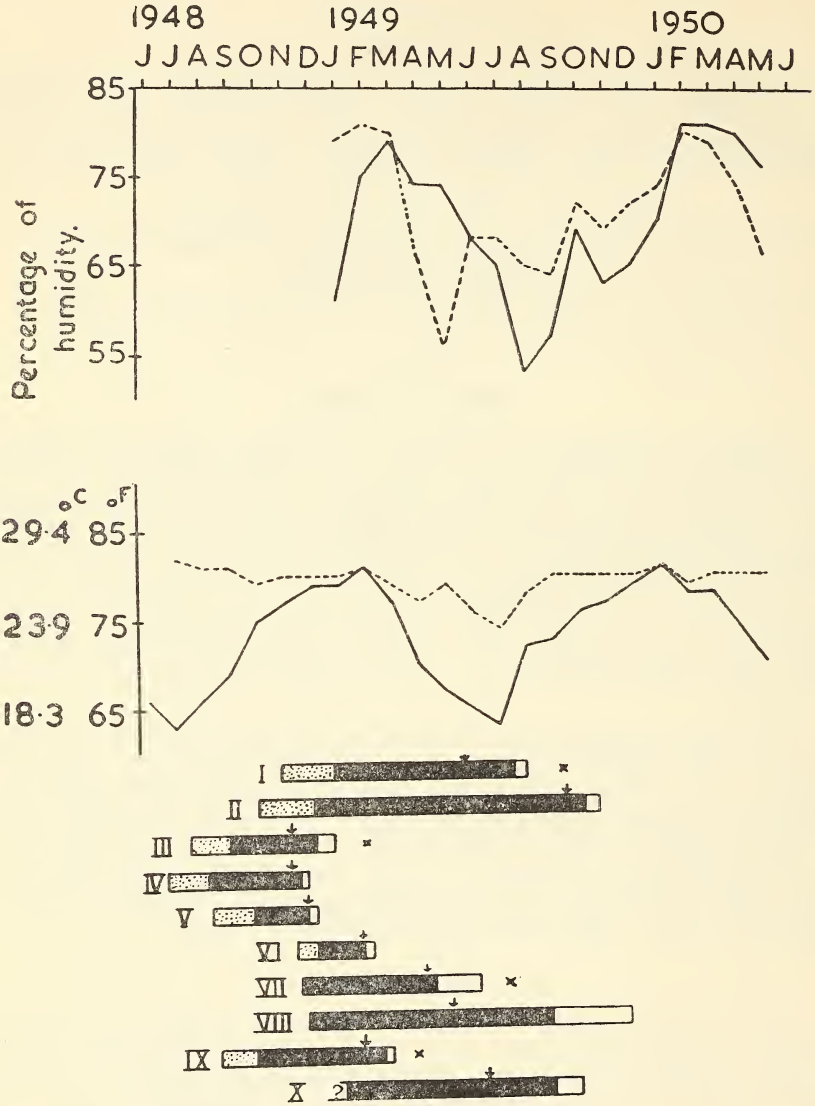
Descriptions of the domestic species are scattered through the literature and are not always readily obtained. Brief systematic descriptions, together with figures, are therefore included to enable those interested to identify the various species at any stage. An account of the life history of each species is given. While many records of the life histories of *Periplaneta americana*, *Blattella germanica* and *Supella supellectilium* have been published, references to *P. australasiae* and *Nauphoeta cinerea* are relatively scanty. None was found concerning *P. ignota*.

METHODS.

Most of the domestic cockroaches were easy to breed in laboratory colonies. Some colonies were kept at room temperature and others in a heated cupboard maintaining a temperature ranging from 73° to 84°F. (22·8°–28·9°C). The graphs (text-fig. 1) show the monthly means of the percentage of humidity and the temperatures in the cupboard and the room.

Egg-capsules were isolated as soon as they were found and all nymphs hatching from one egg-capsule were set up as a colony. Notes were made on the incubation period, the duration of nymphal period, the appearance of the first adult of each sex, the first egg-capsule produced and the total length of life. In addition single females were isolated with one or more males to obtain information about their egg-laying capacity.

The cockroach colonies were usually set up in dressing jars, measuring 6″ x 6″, and several layers of muslin were used as covers for the tops. The bottom of the jar was covered with sterile sand ; pieces of bark and filter paper gave extra surface area. Water was supplied in small dressing



Text–fig. 1. Above. Four graphs showing the monthly means of the percentage of humidity (at 9 a.m.) and the temperature of the heated cupboard (broken line), the room (full line). Below. A diagram of the egg-to-egg cycles of domestic species of Blattidae.

Stippled area	Egg incubation period.
Black area	Hatching to first female adult in a colony. (Appearance of first male marked by an arrow).
Blank area	Preoviposition period.
X	Marks colonies kept in the heated cupboard.

I.–II. *P. australasiae,* III.–VI. *B. germanica,* VII.–VIII. *N. cinerea,* IX.–X. *S. supellectilium.*

jars, 1" x 2", filled with wet cotton wool. Food consisted of a mixture of dried milk, dried yeast, and cracked corn or wheat. Cake, "Farex," bran and fresh apple were also given from time to time.

At first ether was used as an anaesthetic when it was necessary to sex adults, or to transfer a colony to a clean jar. Later carbon dioxide was used and found more satisfactory.

It was very difficult to maintain the right humidity for egg-capsules during incubation. When the humidity was low, they tended to dry out and when it was high, they became mouldy. The best results were obtained by isolating them in sterile test tubes tightly stoppered with cotton wool.

Descriptions have been taken from live insects, since pinned specimens frequently become greasy and the distinctive patterns lost. In all species variations in colour intensity are commonly seen.

A. DOMESTIC SPECIES OF PERIPLANETA.

The genus *Periplaneta* Burmeister (subfamily Blattinae) is represented in Brisbane by three domestic species, *australasiae*, *americana* and *ignota*. As far as I have been able to observe *australasiae* is more usual in dwellings and *americana* in sewers and manholes. The most uncommon is *ignota*.

Their fully developed wings enable them to fly easily into houses on summer nights and they can run very fast. They are particularly averse to daylight, and in three years observation not once were any Periplanetas seen mating in laboratory colonies. These species always ate their own exuviae and dead, and very often their own egg capsules.

Adults of these domestic species are large, brown cockroaches, usually about one to one and a half inches long and having the following characters in common. Light brown head with darker vertex, white ocelliform spots, interocular width less than interantennal, long dark brown antennae, yellowish-brown legs with brown spines, posterior metatarsus longer than the other tarsal segments combined, small pulvilli, arolia present, anterior part of wing yellowish-brown, anal area colourless with brown veins, brown cerci considerably exceeding the supra-anal lamina. The male subgenital plate bears a pair of unsegmented styles, and that of the female is modified to a bivalvular structure (Text–fig. 3j).

The larger nymphs resemble the adults in general conformation. Styles are present in nymphs of both sexes until the final moult when the female loses them.

1. PERIPLANETA AUSTRALASIAE (Fabricius, 1775).

(*a*) DESCRIPTION OF STAGES.

ADULT (Text–fig. 2 AI). Pale yellow pronotum with dark brown margins (considerably wider posteriorly than anteriorly), and with two very dark brown maculae (often fused). Brown tegmina with yellow humeral streaks. Yellowish-brown abdominal tergites and sternites, darkening considerably towards margins and also apex of abdomen; 7th tergite backwardly produced. Dark brown cerci. The genital plates are shown in text–fig. 3.

Total length* :	♂ 26–35 mm.,	♀ 30–35 mm.
Tegmina length :	♂ 23–28 mm.,	♀ 22–25 mm.
Pronotum width :	♂ 8–9 mm.,	♀ 9–11 mm.

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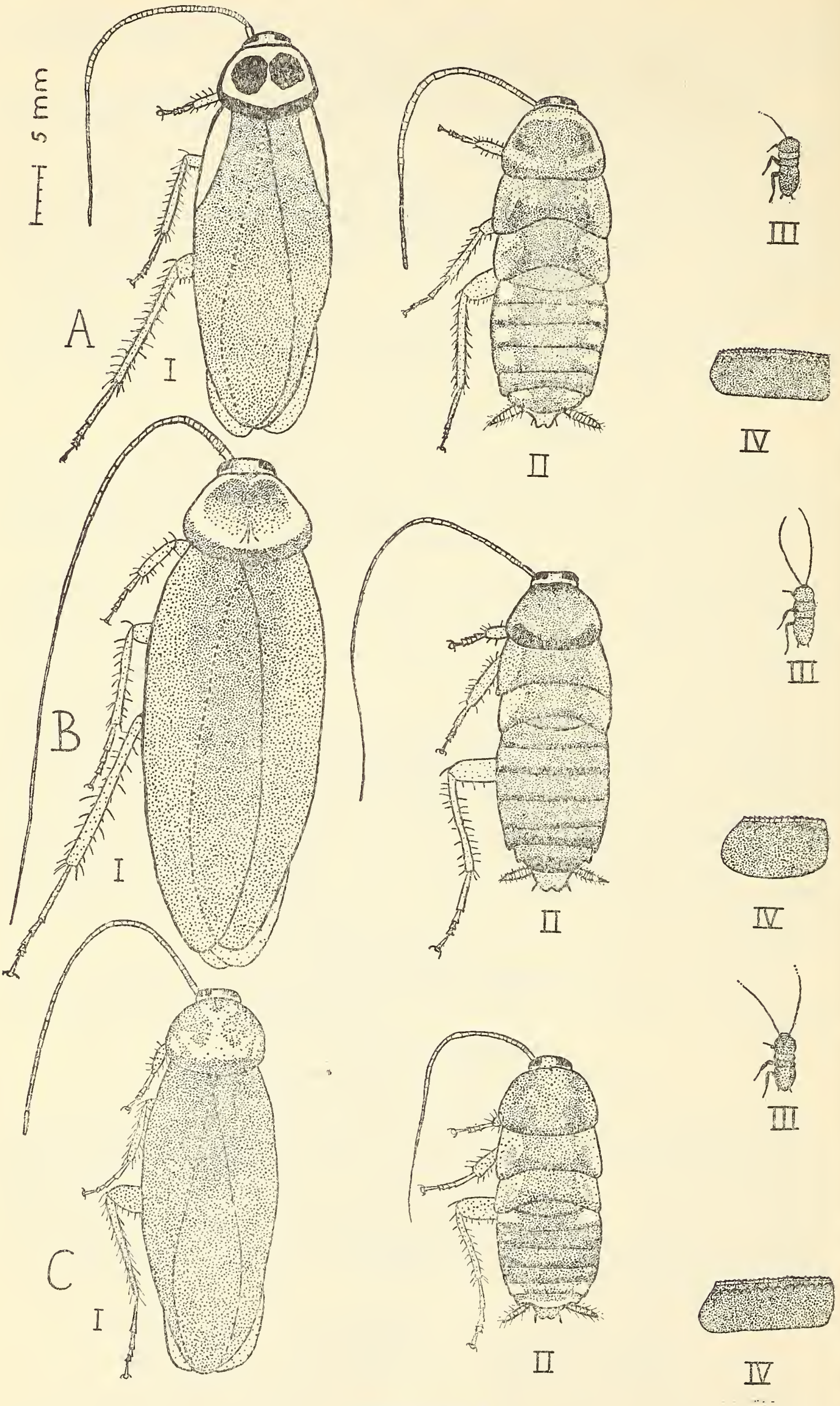
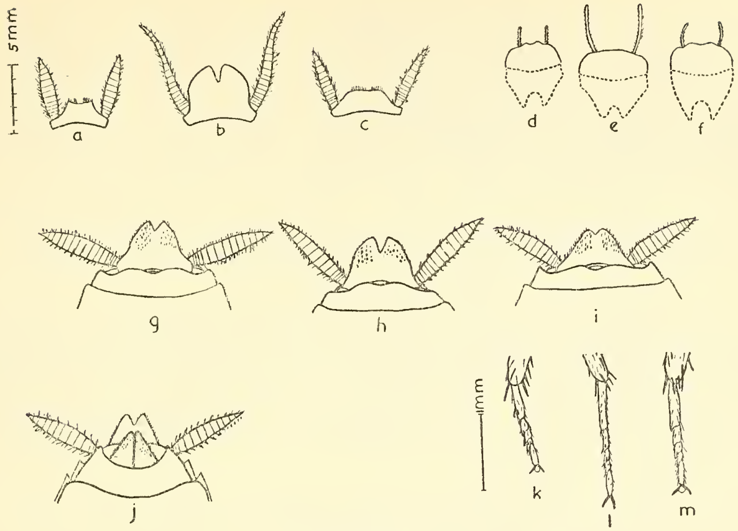
* The total length was measured from the vertex to the tip of the supra-anal plate.



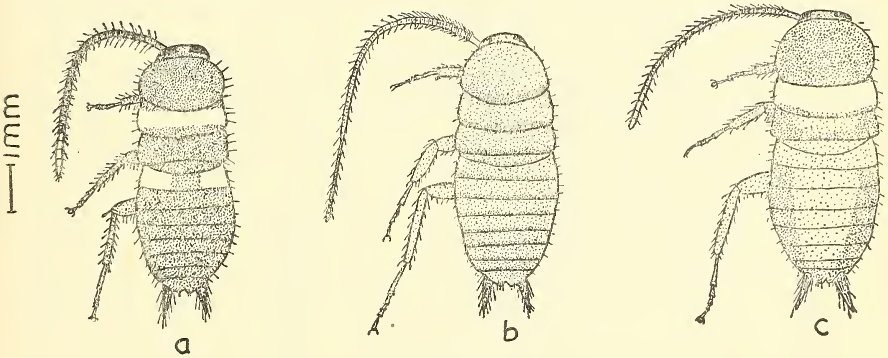
Text–Fig. 2.

A. *P. australasiae*; B. *P. americana*; C. *P. ignota*; I. male adult; II. large nymph; III. newly hatched nymph; IV. egg capsule.



Text–Fig. 3.

Male supra-anal plate: a, *australasiae;* b, *americana;* c, *ignota.* Male subgenital plate: d, *australasiae;* e, *americana;* f, *ignota.* Dorsal view of tip of abdomen of female: g, *australasiae;* h, *americana;* i, *ignota.* Ventral view of tip of female abdomen: j, typical *Periplaneta.* Posterior tarsi of newly hatched nymphs: k, *australasiae;* l, *americana;* m, *ignota.*



Text–Fig. 4.

Newly hatched nymphs (mounted specimens). a, *australasiae;* b, *americana;* c, *ignota.*

LARGE NYMPH (Text–fig. 2 AII). May be distinguished by the following characters:—yellow pronotum with dark margins, considerably wider posteriorly than anteriorly and with two large, dark brown maculae and a brown median smudge which extends to the tip of the abdomen. Mesonotum and metanotum yellowish, with dark brown posterior margins and with translucent wing pads developing in the larger nymphs. Abdominal tergites brown medially, with pale spots ringed with darker brown laterally on second to fifth and on seventh segments. Sternites yellowish-brown. Arolia present.

NEWLY HATCHED NYMPH (Text–figs. 2 AIII and 4a). Head dark, basal segments of antennae pale, four or five apical segments white, remainder black. Dorsal surface dark brown to black with a white band on mesonotum and another on the second abdominal tergite. The latter is interrupted by a median black mark. Legs dark brown, tarsi pale. Arolia present (Text–fig. 3k). Total length, 4–4·5 mm.; antennae length, 4·5 mm.

EGG–CAPSULE (Text–fig. 2 AIV). Dark brown, containing 24–26 eggs side by side in 2 parallel rows. Length, 10–11 mm.; depth, 5 mm.

(*b*) LIFE HISTORY.

(i.) INCUBATION PERIOD. Egg–capsules deposited from October to February (i.e. during summer) hatched in 7 to 8 weeks, those laid in March in 11 to 13 weeks, in April (one record) 23 weeks, in August about 10 weeks and in September 8 to 9 weeks. We have no records of egg-capsules laid during May to July. Those incubated in the warmed cupboard hatched on the average in 53 days.

(ii.) DURATION OF NYMPHAL DEVELOPMENT. There was very great variation in the rate of nymphal development. Although exposed to the same climatic conditions, and having abundant supply of food, a lag of from one to nine months was observed between the appearance of the first and last adult in nymphs derived from a single egg-capsule. At room temperature in summer the shortest period was 156 days for a male and 170 days for a female. There was almost invariably a considerable loss by death between hatching and reaching adulthood, but this could not be calculated at all accurately as dead nymphs (and exuviae) were almost always eaten. Table I. gives the information obtained from some colonies of *P. australasiae*.

TABLE I.

DURATION OF NYMPHAL DEVELOPMENT IN P. AUSTRALASIAE.

Colony Number.	Site.	Date of Hatching.	Period (in Days) from Hatching to Appearance of Adult.		
			Male.	Female.	Final.
200	Room	16 Feb.	316	338	—
2	,, ...	31 Mar.	310	330	596
50	,, ...	21 Sept.	156	170	374
106	,, ...	25 Nov.	309	335	410
110	,, ...	26 Nov.	308	334	381
58	,, ...	1 Dec.	286	337	337
143	,, ...	15 Dec.	268	301	342
17	Cupboard ..	26 May	195	239	285
30	,, ...	21 July	184	223	236
68	,, ...	19 Oct.	140	167	172
97	,, ...	9 Nov.	134	192	272
151	,, ...	29 Dec.	142	198	373

(iii.) EGG-LAYING CAPACITY. At room temperature females produced their first egg-capsule 15 to 48 days after their final moult, adult males being already present in the colony. The average period observed was 21 days. In the warmed cupboard the range was 11 to 24 days, average 16 days. The minimum interval between ovipositions was 2 days and the maximum 40 days. The productivity of some individual females is set out in Table II.

TABLE II.

THE EGG-LAYING CAPACITY OF SOME P. AUSTRALASIAE FEMALES.

Colony Number.	Site.	Total Number of Egg-Capsules Produced.	Reproductive Period (Days).	Average Interval between Ovipositions (Days).
260	Room	31	251	8
H	,, ...	17	109	7
N	,, ...	20	119	6
Average	,, ...	23	160	7
68A	Cupboard	17	136	9
141	,, ...	31	154	5
267	,, ...	15	108	8
I	,, ...	29	175	7
K	,, ...	29	164	6
Average	,, ...	24	147	7

The reproductive period referred to in Table II. is the interval between the deposition of the first and last egg capsule by a female. In the laboratory colonies the last few egg-capsules produced by a female, before she died, seldom hatched and usually were smaller than the earlier ones.

In the laboratory colonies, *australasiae* females always endeavoured to conceal their egg-capsules with sand particles, or minute pieces of filter paper securely glued in place by a secretion from the mouth. Three days was the longest time a female was seen carrying an egg capsule. The usual time taken to produce and deposit one was 24 hours. It is produced and carried with the serrated ridge dorsally.

Roughly the egg-to-egg cycle of *australasiae* covers 350–400 days at room temperature, and 250–300 days in the warmed cupboard. The cycle is so long that it cannot avoid the influence of the cold winter snap, and consequently at least one period is considerably lengthened.

(iv.) LONGEVITY. The longest periods observed were 937 days for a male and 897 days (i.e. about two and a-half years) for a female, both were kept at room temperature. The average life-span for both sexes is about 18 months. In the warmed cupboard, under conditions similar to continuous summer, cockroaches naturally died sooner. Table III. gives the information obtained from some colonies.

TABLE III.

LONGEVITY OF SOME P. AUSTRALASIAE ADULTS.

Colony Number.	Site.	Hatching to Death (Days).					
		Males (28).			Females (16).		
		Max.	Min.	Mean.	Max.	Min.	Mean.
2	Room	937	392	735 (7)	897	660	748 (3)
50	,, ...	751	427	590 (5)	643	381	502 (7)
17A	Cupboard.. ..	284		284 (1)	645		645 (1)
30A	,, ...	666		666 (1)	533		533 (1)
68	,, ...	713	470	557 (4)	427	359	393 (2)
141	,, ...	687	303	455 (9)	524		524 (1)
K	,, ...	653		653 (1)	476		476 (1)

Numbers in brackets indicate the number of individuals observed.

2. PERIPLANETA AMERICANA (Linnaeus, 1758).

(a) DESCRIPTION OF STAGES.

ADULT (Text–fig. 2 BI). Pale yellow pronotum with brown margins, wider posteriorly than anteriorly, and with two light brown maculae (often fused). Concolorous brown tegmina. Brown abdominal tergites and sternites, 7th tergite not backwardly produced. Light brown cerci. Small arolia present. The genital plates are shown in text–fig. 3.

Total length :	♂ 33–45 mm.,	♀ 31–42 mm.
Tegmina length :	♂ 25–33 mm.,	♀ 23–29 mm.
Pronotum width :	♂ 10–11·5 mm.,	♀ 11–13 mm.

LARGE NYMPH (Text–fig. 2 BII). Almost uniformly brown, without the pale abdominal spots of the other two species. Pronotum with two slightly darker brown fused maculae, and a darker brown posterior margin. Abdominal tergites with darker posterior margins. Sternites brown, small arolia present.

NEWLY HATCHED NYMPH (Text–figs. 2 BIII and 4b). Greyish-brown body darkening slightly towards apex of abdomen. Posterior margins of tergites slightly darker in colour. Long almost translucent antennae. Slightly darker cerci. Legs translucent, arolia absent (Text–fig. 31). Body length, 4·5–5 mm.; antennae length, 7 mm.

EGG-CAPSULE (Text–fig. 2 BIV). Differs from that of *australasiae* in its smaller size and consequently in its more rounded appearance. Contains 16–18 eggs. Length, 8–9 mm.; depth, 5 mm.

(b) LIFE HISTORY.

(i.) INCUBATION PERIOD. Observations were made on about 70 egg-capsules. Those laid from October to February (i.e. during summer) hatched in about 7 weeks, those laid in March in 7 to 8 weeks, in April 10 to 11 weeks, in August in about 9 weeks, and in September in about 8 weeks. We have no records for eggs laid from May to July. The maximum period observed was 99 days. In the warmed cupboard the average incubation period was 50 days.

(ii.) DURATION OF NYMPHAL PERIOD. The rate of development varied greatly, and the recorded lag between the first and last adult was even greater than with *P. australasiae*, ranging from 3 to 11 months. In these observations the shortest period for complete development was 320 days for a male, and 287 days for a female at room temperature. The periods observed in some colonies of *americana* are given in Table IV.

TABLE IV.

DURATION OF NYMPHAL DEVELOPMENT IN P. AMERICANA.

Colony Number.	Site.	Date of Hatching.	Duration (in Days) from Hatching to Appearance of Adult.		
			Male.	Female.	Final.
33	Room	2 Aug.	477	505	813
73	„	26 Oct.	365	359	—
84	„	29 Oct.	320	287	—
98	„	9 Nov.	451	379	714
134	„	19 Nov.	335	337	452
29	Cupboard ..	20 July	325	274	395
340	„	24 Oct.	257	186	—
40	„	25 Oct.	192	134	331
91	„	5 Nov.	160	172	300

(iii.) EGG-LAYING CAPACITY. The preoviposition period varied a good deal with the season. In summer at room temperature and in the warmed cupboard egg-laying usually began about 2 weeks after the female's final moult if males were already present in the colony. The minimum period observed was 13 days.

In some colonies females appeared considerably sooner than males. If left thus unmated, they occasionally laid a few egg-capsules, which usually looked very abnormal and invariably failed to hatch.

Takahashi (1924) reported that *americana* can produce parthenogenetically a few, usually about three, egg capsules during life ; the young from these did not normally hatch, and those that did, failed to mature, However, Griffiths and Tauber (1942a) reported virgin females reproducing parthenogenetically. This phenomenon occurred in 9 capsules laid by 3 of a group of 25 unmated females. As many as 13 nymphs emerged from one capsule.

In an attempt to confirm these findings, 6 virgin females were kept in solitary confinement for periods ranging from 2 to 7 months. Of these, four laid no eggs, one laid one egg-capsule and another laid 2 egg-capsules. These were all soft, pale, obviously abnormal capsules, which failed to hatch.

Females usually carried their eggs for 1 or 2 days. Sometimes they glued them to the glass jar, but quite frequently they deposited them loosely in the sand or food, in contrast to *P. australasiae*, which almost always went to considerable trouble to fasten their eggs securely and to conceal them with debris.

In the warmed cupboard their reproductive capacity was at a maximum 2 to 3 months after reaching the adult stage. Females then produced as many as 7 capsules per month. Thereafter, the number gradually decreased, until, towards the end of life, they laid only 1 or 2 per month. At room temperature much the same thing occurred, but an early winter diapause was followed by renewed activity later in the year. For example a pair was mated in December, egg laying began in January, and the following monthly totals were recorded :—January (5), February (5), March (6), April (2), May (0), June (0), July (3), August (3), September (4), October (5), November (4), December (6), January (5), February (4), March (4), April (1).

It is interesting to note that in this, and in two other colonies, egg-laying was resumed in July—actually the coldest month. The egg-laying capacity of some individuals is set out in Table V.

TABLE V.

THE EGG-LAYING CAPACITY OF SOME P. AMERICANA FEMALES.

Colony Number.	Site.	Total Egg-Capsules.	Reproductive Period (Days).	Average Interval between Ovipositions (Days).
33	Room	57	448	8
73	,, ...	65	437	7
84	,, ...	20	232	12
134	,, ...	68	699	10
Average	,, ...	52	454	8·7
E	Cupboard	34	268	8
F	,, ...	37	246	7
Average	,, ...	36	257	7·5

(iv.) LONGEVITY. The longest period recorded was 1,502 days for a male, and 1217 days for a female kept at room temperature. The corresponding figures for the warmed cupboard were 1233 and 754 days respectively. Table VI. gives the periods observed in some *americana* colonies.

TABLE VI.

LONGEVITY OF SOME P. AMERICANA ADULTS.

Colony Number.	Site.	Hatching to Death (Days).					
		Males (22).			Females (15).		
		Max.	Min.	Mean.	Max.	Min.	Mean.
33	Room ..	1,449	1,023	1,251 (3)	984		984 (1)
73	,, ..	1,429	1,403	1,416 (2)	839		839 (1)
84	,, ..	1,194	942	1,068 (2)	693		693 (1)
98	,, ..	941	885	910 (3)	—	—	—
134	,, ..	1,502	1,329	1,415 (2)	1,217		1,217 (1)
29	Cupboard ..	1,233	841	1,004 (4)	645	533	607 (4)
40	,, ..	794	497	655 (4)	754	528	629 (5)
E	,, ..	1,033		1,033 (1)	469		469 (1)
F	,, ..	998		998 (1)	546		546 (1)

3. PERIPLANETA IGNOTA Shaw, 1925.

(*a*) DESCRIPTION OF STAGES.

ADULT (Text–fig. 2 CI). Light brown pronotum with pale yellow anchor-shaped marking, and darker lateral and posterior margins. Concolorous brown tegmina. Light brown abdominal tergites and sternites, darkening laterally and towards apex of abdomen ; 7th tergite backwardly produced ; dark brown cerci. The genital plates are shown in text–fig. 3.

Total length : ♂ 30–33 mm., ♀ 30–34 mm.
Tegmina length : ♂ 23–25 mm., ♀ 20–22 mm.
Pronotum width : ♂ 9–10 mm., ♀ 10–11 mm.

LARGE NYMPH (Text–fig. 2 CII). Brown pronotum with light median marking. Light brown mesonotum and metanotum with dark posterior margins. Dark brown abdominal tergites with pale lateral spots on 2nd and 6th segments and a pair of very small pale spots on 3rd segment. Light posterior margin on 7th tergite. Brown abdominal sternites darkening laterally.

NEWLY HATCHED NYMPH. (Text–figs. 2 CIII and 4c). Dark brown head. Dark antennae with basal segments pale and five apical ones white. Thoracic tergites brown, white transverse strip on mesonotum. Yellow abdominal tergites and sternites, darkening considerably laterally. Dark cerci. Pale legs with darker edges, arolia present (text–fig. 3m). Length of body, 4·5–5 mm.; length of antennae, 5 mm.

EGG-CAPSULE (Text–fig. 2 CIV). Very similar to that of *australasiae*, but each compartment slightly larger. Contains 22–24 eggs. Length, 12–13 mm.; depth, 5 mm.

(*b*) LIFE HISTORY.

This species is not present in Brisbane in as large numbers as *P. australasiae* and *P. americana*, but it is found occasionally in dwellings. Experiments were begun with a single female, which laid only one egg-capsule in captivity. Additional colonies were set up when the progeny of this female matured and commenced egg-laying. All were kept at room temperature.

(i.) INCUBATION PERIOD. During summer this varied from 49 to 61 days. Eggs laid in March required 11 weeks to hatch. Those laid in April 13 weeks.

(ii.) DURATION OF NYMPHAL PERIOD. All colonies developed during the summer months, the minimum periods observed were 110 days for a male and 126 days for a female. The lag between the appearance of the first and last adults varied from about 6 weeks to 7 months. Table VII. gives the information obtained from 4 colonies of *P. ignota*.

TABLE VII.

DURATION OF NYMPHAL DEVELOPMENT IN P. IGNOTA.

Colony Number.	Date Hatched.	Duration (in Days) from Hatching to Adult.		
		Male.	Female.	Final.
93	31 Dec.	110	248	327
368	28 Nov.	295	126	295
375	12 Dec.	289	257	301
388	23 Dec.	270	158	311

(iii.) EGG-LAYING CAPACITY. From two colonies containing groups of two and three females respectively, 59 and 89 egg-capsules were removed, so on an average one female could produce nearly 30 egg capsules. Unfortunately in each of these groups all the males died before the reproductive period of the females had ended. Females were observed to carry an egg-capsule for 1–2 days. They usually concealed their eggs in the sand, glueing them firmly to the bottom of the jar. In this habit and in the size of the egg-capsule they closely resembled *P. australasiae*. Females usually deposited their first egg capsule about 12 days after reaching adulthood. Thereafter they deposited them at intervals of about a week.

(iv.) LONGEVITY. The periods observed in the original colony were from 248 to 452 days, mean 390 days, for 7 males; and 515 to 732 days, mean 646 days, for 5 females.

B. OTHER DOMESTIC SPECIES.

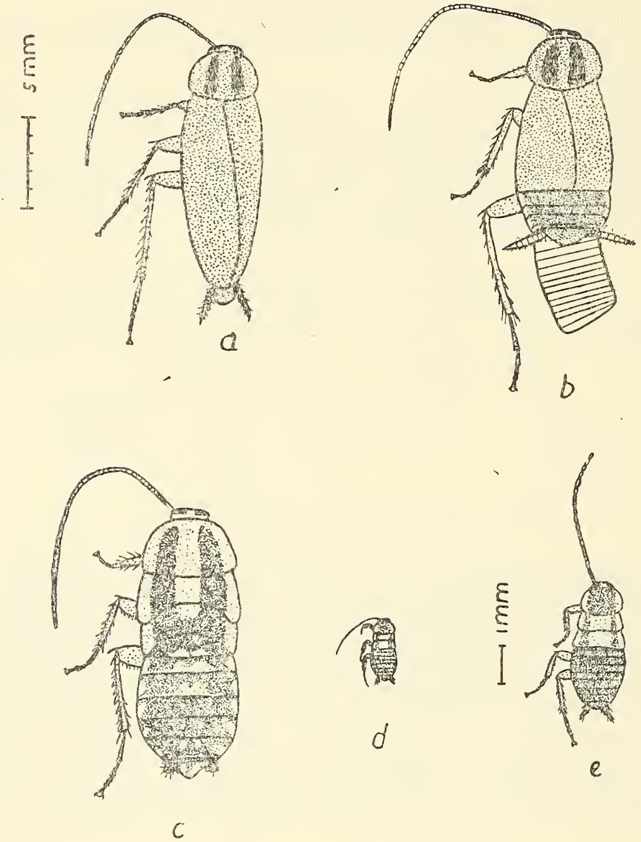
Other domestic species of Blattidae occurring in Brisbane are *Blattella germanica* (Linn.) and *Supella supellectilium* (Serv.), (subfamily Pseudomopinae). *Nauphoeta cinerea* (Oliv.) (subfamily Panchlorinae) has been regarded as " semi-domestic", since it is found in outhouses and stores rather than in dwellings.

Froggatt (1906) noted that *B. germanica* was first recorded in Australia by Tepper (queried 1893, confirmed 1905).

B. germanica and *S. supellectilium* are small, light brown, very active species about half an inch long. The former has two very distinctive, longitudinal, black stripes on its pronotum ; the females carry their egg-capsules attached to their bodies until the young are ready to hatch. The latter has a plain brown pronotum with transparent edges; the females deposit their egg capsules soon after they are produced. *N. cinerea* is a large, speckled, greyish-brown, sluggish species; the females are viviparous.

1. BLATTELLA GERMANICA (Linnaeus, 1767).

(*a*) Description of Stages.



Text–Fig. 5.

B. germanica. a, male adult; b, female adult with wings clipped to show egg-capsule; c, large nymph; d, and e, newly hatched nymph.

Adult male (Text–fig. 5a). Light brown head with dark brown stripe on anterior edge of vertex, interocular width slightly less than interantennal, white ocelliform spots and small brown median dot on frons, slightly darker antennae. Light brown thoracic tergites with two longitudinal, parallel, black stripes. Light brown, concolorous tegmina; pale, almost colourless, wings with light brown costal and apical margins; tegmina and wings extending to tip of abdomen. First abdominal tergite rounded and darker than rest, 2nd to 6th tergite yellowish, with dark brown subapical markings laterally, and a pair of small transverse dark brown medial basal markings, 7th and 8th tergites light brown with glandular pockets,* 9th light brown with dark brown median marks; 2nd to 6th

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* Wille (1921) reported that copulation is preceded by a lengthy love-play in which the female touches the dorsal glands of the male and then later licks them.

tergites with slight rounded backward projections, abdomen long and slender in shape. Some dark thoracic sternal plates; light brown abdominal sternites. Light brown legs, coxae with slight black streaks, posterior metatarsus longer than other tarsal joints together; light brown cerci considerably exceeding supra-anal lamina.

(*b*) FEMALE (Text–fig. 5b). Differs from the male in—

(i.) Genital plates (text–fig. 6). The emargination on the female supra-anal plate varies in its size, and even may be completely absent.

(ii.) General size. About the same length as the male, but abdomen is much broader, reaching, and often extending beyond, the tips of the tegmina (except when she is carrying an egg-capsule).

(iii.) Colour. (*a*) Generally much darker than the male; (*b*) size and intensity of dark marking on frons greater than in males.

Total length :	♂ 14 mm., ♀ 14 mm.
Tegmina length :	♂ 10 mm., ♀ 10·5 mm.
Pronotum width :	♂ 3·5 mm., ♀ 4 mm.

LARGE NYMPH (Text–fig. 5c). Dark brown head, light brown vertex. Yellow thoracic tergites with two wide longitudinal, dark brown stripes, sometimes joining posteriorly on metanotum. Dark brown abdominal tergites with pale dots on lateral margins becoming smaller towards 7th tergite, and two median light brown dots on each tergite, most conspicuous on 2nd, 3rd, 4th and 7th. Brown abdominal sternites darkening towards apex and with pale lateral margins. Supra-anal plate mottled. Long dark brown cerci always standing upright. Pale yellow legs, coxae darker at base. Styles present in both sexes until the final nymphal moult, when those of the female disappear and those of the males remain. (There is great variation in the intensity of the light brown, median markings on the abdominal tergites of large nymphs).

NEWLY HATCHED NYMPH (Text–fig. 5d, e). Dark brown head and body. Thoracic tergites with transparent edges, 2nd and 3rd with wide yellow portion. Light brown, almost translucent legs with dark streak on coxae; arolia present. Dark brown antennae with pale basal segments. Styles present in both sexes. Body length, 3 mm.; antennae length, 3·5 mm.

EGG-CAPSULE (Text–fig. 5b). Light brown, slightly darker at outermost end, and almost white at end attached to female's body; roughly rectangular in shape; usually contains 38–40 eggs. Length, 8 mm.; depth, 3 mm.

(*b*) LIFE HISTORY.

The egg capsule of *germanica* in its early period of formation was noticed protruding from the abdomen of the female with the serrated ridge in a dorsal position. When the capsule was almost fully extruded, it rotated, and finally rested with the ridge lateral on the right side, when looking at the female dorsally (*See* text–fig. 5b). It remained in this position until the young were ready to hatch. Several instances showed that the capsules would hatch after being removed from the female, only if they were well matured, and not even slightly damaged when removed. The abdomen of a female was always very contracted while she was carrying a capsule.

(i.) INCUBATION PERIOD. At room temperature egg-capsules hatching in midsummer were carried by a female for an average period of 24 days, while in winter the time was 42 days. In the cupboard the average was 28 days.

(ii.) DURATION OF NYMPHAL DEVELOPMENT. The period of nymphal development varied considerably according to the time of year when the young were born. Those hatching in summer, or kept in the warmed cupboard, developed very rapidly, reaching maturity in 7 to 10 weeks, whereas those hatching in winter required over 4 months. Males usually appeared first in a colony, but there was seldom a very great difference between the sexes. The lag between the first and last adult, which was such a marked feature in *Periplaneta* colonies seldom occurred, except in colonies reaching maturity late in summer, when those nymphs which were slowest in development were caught by the winter cold, and went on developing slowly for several months after the first adults had appeared (colony number 189). The results obtained in some colonies are set out in Table VIII.

TABLE VIII.

DURATION OF NYMPHAL DEVELOPMENT IN B. GERMANICA.

Colony Number.	Site.	Date of Hatching.	Duration (in Days) from Hatching to Appearance of Adult.		
			Male.	Female.	Final.
80	Room	3 Jan.	58	64	95
189	,,	9 Feb.	55	63	212
15	,,	21 May	139	147	161
25	,,	23 June	138	147	147
12	,,	2 July	98	107	114
41	,,	24 Sept.	61	61	76
126	,,	26 Nov.	53	56	69
132	,,	6 Dec.	49	49	65
24	Cupboard	15 June	76	80	101
27	,,	30 July	70	95	121
38	,,	30 Sept.	69	63	121
65	,,	29 Oct.	63	74	84

(iii.) NUMBER OF MOULTS. The determination of the number of moults is difficult and tedious owing to the habit of most cockroaches eating their exuviae. A special arrangement is necessary and it was attempted only for *B. germanica.*

One or at most two newly-hatched nymphs were placed in a test tube, fed on dried milk and yeast and watered by a 2 cc. ampoule full of water plugged in the mouth of the test tube. They were kept in the warmed cupboard. Daily examinations were made and the width of the head capsule was measured at frequent intervals after anaesthetising the insect with carbon dioxide. It was usually possible to predict when a nymph was about to moult by the stretched appearance of the body.

Of a large number of nymphs set up in this way, 29 became adults, 8 females and 21 males. Eleven males became adult after the sixth moult, but all the females and 10 of the males passed through seven moults before reaching the adult stage.

(iv.) EGG-LAYING CAPACITY. Females usually produced 4 or 5 egg-capsules.

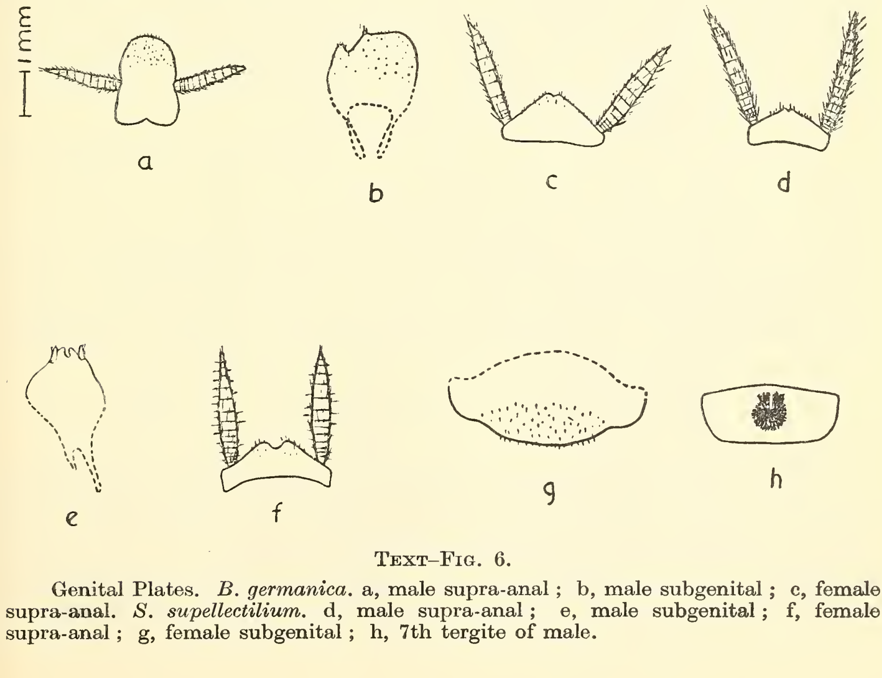
(v.) LONGEVITY. *B. germanica* is a relatively short-lived cockroach, living on an average about 9 or 10 months. Observations on 9 pairs which were kept at room temperature, gave the following figures :—Males, maximum 343, minimum 177, mean 260 days ; females, maximum 384, minimum 202, mean 297 days.

The egg-to-egg cycle was taken from the day a female was carrying a fully formed capsule until the day the first one of the progeny from that egg case was carrying a capsule. In seven colonies kept at room temperature the average duration of this cycle was 140 days. The maximum was 206 days for one beginning in the early winter and the minimum 88 in the early summer. In the controlled cupboard the cycle varied from 109 to 162 days.

2. SUPELLA SUPELLECTILIUM (Serville, 1839).

Dr. Eland Shaw recorded the presence of this insect in Queensland in 1924 when he wrote " *S. supellectilium* (Serv.) occurs as a domestic insect in company with the common *Blattella germanica* (Linn.) and seems capable of even more rapid multiplication than that species. Its spread over Australia generally is to be expected " (Shaw, 1924). In 1925 he wrote " . . . . when *Supella supellectilium* (Serv.) invades places already occupied by *Blattella germanica* (L.), it tends to oust the latter." (Shaw, 1925, p. 205). This species is widespread in Brisbane at the present time, but usually it is found only in small numbers. We always had very great difficulty in establishing laboratory colonies, and *supellectilium* proved to be the most delicate of all the domestic species. It seems doubtful if it could oust *B. germanica* in Queensland.

The male is generally a pale yellowish colour with fully developed wings extending beyond the tip of its narrow, pale abdomen. The female is generally darker and much broader than the male ; her shorter wings do not reach the tip of the abdomen. The nymphs of this species can run fast and jump well.

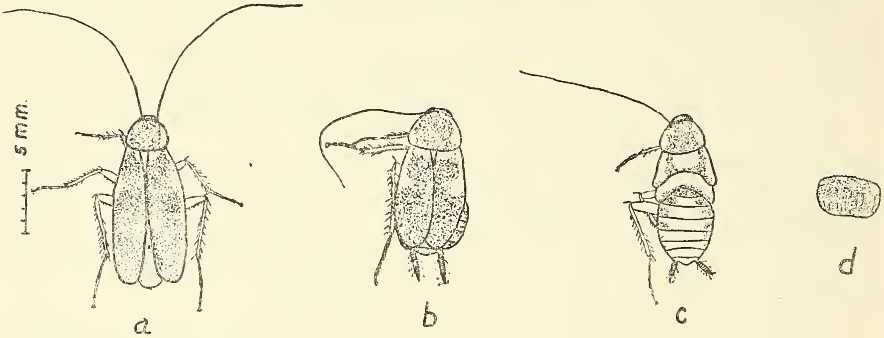


TEXT–FIG. 6.

Genital Plates. *B. germanica*. a, male supra-anal ; b, male subgenital ; c, female supra-anal. *S. supellectilium*. d, male supra-anal ; e, male subgenital ; f, female supra-anal ; g, female subgenital ; h, 7th tergite of male.

(*a*) DESCRIPTION OF STAGES.

ADULT (*a*) MALE (Text–fig. 7a). Yellow to yellowish-brown head (sometimes with rather orange vertex), white ocelliform spots, brown dot below each antennal socket, interocular width less than interantennal, dark brown antennae. Pronotum brown over body with transparent anterior and lateral edges, very narrow, dark margin all round and narrow yellow median stripe. Pale yellowish brown tegmina with transparent humeral area, slight paleness in base of dividing vein with effect of a darker brown band just below; wings colourless with slight brown marking at apex; tegmina and wings both extending beyond tip of abdomen. First five abdominal tergites colourless, remainder yellow, 7th with characteristic brown impressed area (text–fig. 6h); postero-lateral angles of tergites not backwardly produced. Supra-anal plate with slight emargination (text–fig. 6d). Some dark thoracic sternites, abdominal sternites darkening to orange at apex; general shape of abdomen slender. Subgenital plate narrow, roughly triangular with lobe-like styles (text–fig. 6a). Pale yellowish legs darkening to orange tarsi, posterior metatarsus longer than other tarsal joints together, pulvilli small and inconspicuous, arolia present, tarsal claws symmetrical. Pale yellow cerci darkening towards tip, extending considerably beyond supra-anal lamina.



TEXT–FIG. 7.

S. supellectilium. a, male adult; b, female adult; c, large nymph; d, egg capsule.

(*b*) FEMALE (Text–fig. 7b). Short, brown tegmina with transparent humeral margin with two incomplete transverse colourless bands near base; tegmina and wings covering about three-fifths of abdomen. Abdominal tergites yellow with brown markings laterally on third to fifth segments, sixth brown, remainder with centre brown and lateral portions pale. Some dark thoracic sternal plates, abdominal sternites orange, darkening towards apex of abdomen. Supra-anal plate with small emargination (text–fig. 6f). Subgenital plate orange, ample, rounded (text–fig. 6g).

Total length:	♂ and	♀ 12–13 mm.	
Tegmina length:	♂ 11–12 mm.,	♀	8–9 mm.
Pronotum width:	♂ and	♀ 3·5–4·5 mm.	

LARGE NYMPH (Text–fig. 7c). Dark brown head, usually lighter above antennal sockets, antennae with yellowish-brown base, darkening to black tips. Pronotum dark brown over body with transparent anterior and lateral edges and some variable light marking in centre; very pale yellow mesonotum with H-shaped dark area; pale yellow metanotum with dark posterior margin. First abdominal tergite very dark brown, others pale yellow (2nd to 5th with dark brown, lateral marks). Some dark thoracic sternal plates; yellowish abdominal sternites. Supra-anal plate with small lateral dark marks, rounded triangular shape, no emargination. Very pale yellow coxae and femora, more orange tibiae and tarsi. Cerci pale at base, dark at apex.

NEWLY HATCHED NYMPH. General colouration light greyish-brown. Pronotum with pale lateral margins, mesanotum with central third white, sides and posterior margins light brown, metanotum mainly white with a light greyish-brown area on each side near anterior margin and along posterior margin. Tergites light greyish-brown, ventral surface pale. Legs very pale yellow almost translucent. Antennae similar in colour to body except for the third segment which is paler. Styles present in both sexes. Arolia present. Length, 2·6 mm.; antennae, 4 mm.

EGG-CAPSULE (Text–fig. 7d). Light brown, concolorous. As eggs mature a definite medio-lateral green tinge develops. Usually containing 18 eggs, range 16–20. Length, 5 mm.; depth, 3 mm.

(*b*) LIFE HISTORY.

S. supellectilium appeared very fond of the gum on the backs of labels and consequently some were included in its regular diet.

(i.) INCUBATION PERIOD. The incubation period varied from 63 to 156 days. Eggs laid in July did not hatch until October; August eggs hatched in November (about 90 days); those laid in November hatched in 63 days. Eggs laid in March at the end of summer did not hatch until July and August (maximum period observed 156 days). In the warmed cupboard they hatched in 7 weeks.

(ii.) DURATION OF NYMPHAL DEVELOPMENT. The period of nymphal development varied considerably with the season; however, even in mid-summer its development was slower than that of *B. germanica*. The minimum period observed was 90 days for a male and 98 days for a female, developing at room temperature in mid-summer, the maximum period observed from hatching to the appearance of the first adults was 223 days in a colony hatching in late summer. The results obtained from some colonies are set out in Table IX.

TABLE IX.

DURATION OF NYMPHAL DEVELOPMENT OF S. SUPELLECTILIUM.

Colony Number.	Site.	Date of Hatching.	Duration (in Days) from Hatching to Appearance of Adult.		
			Male.	Female.	Final.
163	Room	5 Jan.	161	236	355
239	,,	11 Mar.	223	223	241
92	,,	5 Nov.	90	98	117
225	,,	22 Nov.	217	217	240
37	Cupboard	1 Sept.	96	114	138
42	,,	14 Sept.	121	153	153
52	,,	23 Sept.	124	148	249
59	,,	2 Oct.	150	136	255
90	,,	4 Nov.	117	111	182

(iii.) EGG-LAYING CAPACITY. The preoviposition period varied from 8 to 9 days in the warmed cupboard to 63 days for a pair mated at the beginning of winter at room temperature. Females usually carried their egg-capsules for 1 or 2 days, but occasionally were observed to carry them for longer periods up to 8 days. The capsules were produced and carried with the ridge dorsal. Females laid from 6 to 25 capsules, the average for 7 pairs being 14. Isolated females laid eggs at intervals ranging from 3 to 13 days, the most frequently observed interval being 7 days.

In several instances unmated *supellectilium* females produced either apparently normal egg cases that failed to hatch, or a mass of whitish eggs not covered at all by a capsule. The latter soon dried and shrivelled on coming in contact with the air.

(iv.) LONGEVITY. *S. supellectilium* has a rather longer life-span than *B. germanica*, the average period being a little greater than one year. It must be remembered that it was the least adaptable of the domestic species. Many nymphs died before reaching maturity and it is possible that under more favourable conditions, it would live longer than in our laboratory colonies. The longevity of some adults is set out in Table X.

TABLE X.

THE LONGEVITY OF SOME S. SUPELLECTILIUM ADULTS.

Sex.	Place Reared.	Longevity (Days).		
		Max.	Min.	Mean.
Male ..	Room	667	259	490 (6)
	Cupboard	397	173	272 (7)
Female ..	Room	538	154	385 (6)
	Cupboard	240	207	228 (3)

Figures in brackets indicate number of individuals.

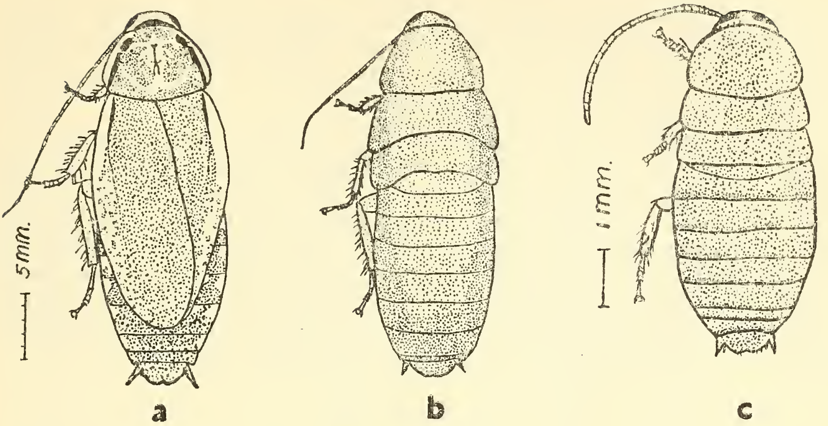
3. NAUPHOETA CINEREA (Olivier, 1789).

This is a "semi-domestic" species. Although adults have been found in dwellings, there have been no reports of its breeding there. Usually this species is associated with grain stores and fowl-feeding pens. No record of the life history of this species was found in Australian literature. It was first recorded in Australia by Shaw (1918), having been taken at various localities between Brisbane and Cairns.

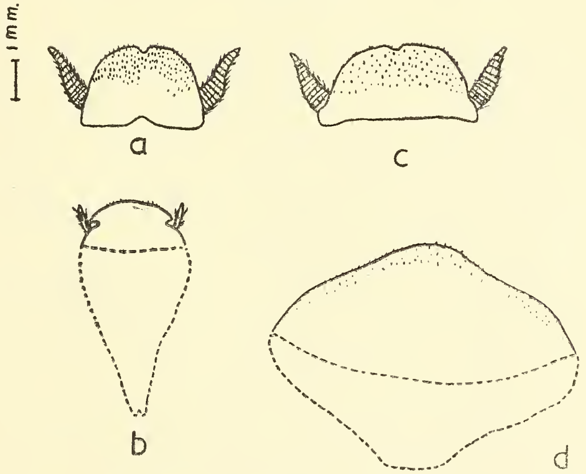
Both sexes have fully developed wings, which fall just short of the tip of the abdomen. They have short, stout legs, and cannot run as fast as the domestic species. They have a more scuttling movement. The male subgenital plate bears a pair of unsegmented styles. The female's body is larger than that of the male.

(*a*) DESCRIPTION OF STAGES.

ADULT (Text–fig. 8). Fawn head with dark brown interocular band, light interantennal band, interocular width less than interantennal, white ocelliform spots, pale palps. Medium brown pronotum with fawn lateral margins and symmetrical fawn picturing, dark brown, longitudinal stripe on lateral edge of pronotal disc. Medium brown tegmina speckled with white, translucent fawn costal area ; colourless wings with medium brown veins ; tegmina and wings reaching at least to 7th tergite. Abdominal tergites medium brown with white markings ; 1st to 7th not backwardly



TEXT-FIG. 8.
N. cinerea. a, male adult ; b, large nymph ; c, newly hatched nymph (mounted specimen).



TEXT-FIG. 9.
N. cinerea. Genital plates, a, male supra-anal ; b, male subgenital ; c, female supra-anal ; d, female subgenital.

produced, 8th only slightly so, abdominal sternites medium brown with a few white markings, darkening towards apex. Pale legs, femora unarmed beneath, short tibiae, large pulvilli, large arolia, tarsal claws symmetrical. Supra-anal lamina rounded, one median notch on posterior margin (text-fig. 9a male, and 9c female) ; pale cerci only slightly exceeding this lamina. Male subgenital plate with a pair of unsegmented styles (text-fig. 9b) ; female subgenital plate ample, rounded (text-fig. 9d).

Total length :	♂ 27–29 mm.,	♀ 29–31 mm.
Tegmina length :	♂ 16–17 mm.,	♀ 18–20 mm.
Pronotum width :	♂ 7–8·5 mm.,	♀ 9–10 mm.

LARGE NYMPH (Text-fig. 8b). Medium brown, shiny head and body. White ocelliform spots, eyes slightly reduced, interocular width about equal to interantennal, brown antennae, paler clypeus. Thoracic tergites with very dark brown lateral margins ; abdominal tergites with dark lateral and posterior margins, generally darkening towards apex of abdomen; only 8th slightly backwardly produced. Some dark thoracic sternal plates; anterior abdominal sternites with median yellow tinge. Lighter brown legs with dark spines on short tibiae; large arolia. Medium brown cerci not extending beyond supra-anal lamina.

NEWLY HATCHED NYMPH (Text–fig. 8c). Head with greyish-brown vertex, becoming paler towards the clypeus, palps translucent, eyes reduced, interocular space greater than inter-antennal space, slightly darker antennae. Greyish-brown body; abdominal tergites with slightly darker posterior margins; ventral surface of abdomen grey, darkening laterally and towards its apex. Supra-anal plate produced, one median notch; short cerci not projecting beyond this plate. Styles present in both sexes. Light brown, almost translucent legs, tarsal claws symmetrical, large arolia. Body length, 5 mm.; pronotum width, 2 mm.

(*b*) LIFE HISTORY.

In the laboratory this species was found to be particularly fond of cracked maize, consequently this formed the main part of its diet, supplemented by dried milk, dried yeast and fresh apple. It will eat its own exuviae and dead (sometimes even before specimens are dead).

Mating was never observed in this species, although sometimes the males would be seen running around the jars with their backs arched and their wings standing upright. It is presumed that mating occurs at night. The females are viviparous. The eggs are formed side by side in a double row into an egg mass similar to that of other species. *N. cinerea* females retain their egg mass, covered by a soft, transparent membrane within their bodies until the young are ready to hatch. The plane of the egg mass is parallel to that of the female's body.

(i.) INCUBATION PERIOD. As mating was not observed, and no egg-capsule is produced, the length of the period of gestation was never observed accurately. The period of gestation covers the interval from the pairing of a male and a female to the production of young. Possible periods of gestation were calculated from the appearance of a newly moulted adult female in a colony, where one or more adult males were already present, to the production of the first batch of young. These periods varied from 50 to 196 days, mean 105 days, at room temperature, and from 44 to 102 days, mean 64 days, in the warmed cupboard.

(ii.) EGG-LAYING CAPACITY. One female can produce as many as 4 " egg masses " each containing 30–40 eggs, usually at intervals of about 2 months. Often an old female produced a " premature " mass of creamish eggs, which did not hatch. On coming in contact with the air, it immediately hardened and shrivelled.

(iii.) DURATION OF NYMPHAL DEVELOPMENT. The rate of nymphal development was surprisingly rapid for such a large, sluggish insect. The shortest period was 107 days in a colony set up in early summer. Males usually appeared first. The results observed in some colonies are set out in Table XI.

(iv.) LONGEVITY. *N. cinerea* is a long-lived species. The maximum life-span recorded was 1,185 days for a male, and 1,026 days for a female. Table XII gives the periods observed for some adults.

The " egg-to-egg " cycle, measured from the production of one batch of young until the latter produced their first young, varied from 295 to 481 days, mean 372 days at room temperature (6 observations); and 182 to 246 days, mean 221 days in the warmed cupboard (5 observations).

TABLE XI.

DURATION OF NYMPHAL DEVELOPMENT OF N. CINEREA.

Colony Number.	Site.	Date of Birth.	Birth to Appearance of Adult (Days).		
			Male.	Female.	Final.
161	Room	10 Jan.	241	254	336
190	,,	7 Feb.	211	226	322
4	,,	1 Mar.	279	322	332
31	,,	30 July	215	285	285
109	,,	24 Nov.	119	141	407
107	,,	25 Nov.	161	279	—
124	,,	30 Nov.	107	156	274
149	,,	20 Dec.	213	338	470
22	Cupboard	21 Jan.	112*		209
3A	,,	2 Feb.	187	191	342
3	,,	6 Apr.	189	202	261
108	,,	19 Nov.	136	146	—
136	,,	8 Dec.	139	—	243

* Sex not recorded.

TABLE XII.

THE LONGEVITY OF SOME N. CINEREA ADULTS.

Sex.	Place Reared.	Longevity (Days).		
		Max.	Min.	Mean.
Male	Room	1,185	324	550 (10)
	Cupboard	646	383	473 (3)
Female	Room	1,026	381	803 (3)
	Cupboard	619	296	398 (10)

DISCUSSION.

In the accessible literature are descriptions of the biology and life histories of various cosmopolitan domestic species of Blattidae. *Blatta orientalis* Linn., *Periplaneta americana* (Linn.), *P. australasiae* (Fabr.), *Blatella germanica* (Linn.), and *Supella supellectilium* (Serv.). All these species, with the exception of *B. orientalis**, are common in Brisbane at present.

It is interesting to notice that the species which have become domestic pests in Queensland are all cosmopolitan and have been introduced. The possible exception is *Periplaneta australasiae* (Fabr.). The origin of this insect is not at all clear. Froggatt (1906) recorded that it was then rare near Sydney, N.S.W., and regarded it as remarkable that a species not common in its own country had become a serious domestic pest when introduced into America. There seems no doubt that it was widespread in America at the beginning of this century. Marlatt (1902) reported that it was the most abundant and troublesome species in Florida. Shaw (1925) considered that Fabricius used *australasiae* to mean " of Southern Asia," since the term Australasia as applied to Australia and New Zealand was not in use when he described the insect in 1775. Probably it is also an

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* The specimens of *Blatta orientalis* in the Eland Shaw collection in the Queensland Museum were obtained at Kadina, S.A.

introduced pest. *P. ignota* Shaw was first described in 1925 from specimens collected in Queensland, Shaw (1925). It is probably an endemic species, but it is not abundant enough to be regarded as a serious pest.

P. americana was studied by Haber (1920) in U.S.A., Takahashi (1924) in Formosa, Fischer (1928) in Germany, Nigam (1933) in India, Klein (1933) in Palestine, and Gould and Deay (1938), Rau (1940) and Griffiths and Tauber (1942) all in U.S.A. Studies of *B. orientalis* were carried out by Miall and Denny (1885) in England, Rau (1924) in U.S.A., Zabinski (1929) in Europe and Qadri (1938) in England. The development of *B. germanica* was observed by Wille (1921) in Germany, and Woodruff (1938) in U.S.A. *S. supellectilium* was studied by Cottam (1922) in Khartoum, and Back (1937) in U.S.A.

The works of Marlatt (1915), Haber (1919), and Laing (1921) included the above species except *S. supellectilium*, while the later reports of Gould and Deay (1938 to 1940), Gould (1941) and Metcalf and Flint (1939) covered them all, and included some others. Laing carried out his studies in Britain, and the others in America.

When allowance is made for climatic differences, our findings agree fairly well with those of the authors quoted. Gould and Deay (1938) found the incubation period of *P. americana* to vary from 35 to 100 days, the average for over 400 egg-capsules being 55 days. They found an average preoviposition period of 13·4 days, and that one female could produce 59 eggs at an average interval of 5·9 days. The nymphal period varied from 285 to 616 days, average 409 days at a temperature range of 68° to 82° F., with relative humidity ranging from 27 to 61%. These authors noted that the males of *P. americana* were usually longer in reaching the adult stage than the females. This also occurred in our colonies. With *P. ignota* (in the limited number of colonies observed) and with *P. australasiae* the reverse was usually true. Gould and Deay (1938) record a maximum life span for *P. americana* of 913 days, but Griffiths and Tauber (1942) report that the life-span may exceed 1,200 days. A maximum of 1,502 days is recorded here.

B. germanica has probably been studied more intensively than any other species. Gould (1941) records an egg-laying capacity of 5 capsules per female, a figure which agrees well with my results. Laing (1921), recorded a maximum of 7 egg-capsules per female. However, it seems clear that this species lays relatively few egg-capsules ; its abundance is due to its rapid development, to the large number of nymphs (38–40) produced from each capsule, and to the greater protection from both enemies and desiccation afforded to the eggs by being carried by the female during incubation.

S. supellectilium produces a small egg-capsule usually containing only 15–18 nymphs. The incubation period is a relatively long one and nymphal development is slow. These factors probably contribute to its scarcity in comparison with *B. germanica*. Gould and Deay (1940) gave a good account of its life history in America. They found an incubation period of 90 days at 73°F. and 49 days at 82°F. Nymphal development required 161 days at room temperature, and 92 days at 84°F. Females produced about 15 egg-capsules containing about 13 nymphs. The minimum incubation period recorded by Cottam (1922) working in Khartoum was 33 days.

Illingworth (1941) studied *N. cinerea* and recorded its viviparous nature, finding 28–40 young produced at each birth. He also noted its association with poultry food sheds in Honolulu.

SUMMARY.

The domestic species of Blattidae occurring in Brisbane are *Periplaneta australasiae* (Fabr.), *P. americana* (Linn.), *P. ignota* Shaw, *Blattella germanica* (Linn.), and *Supella supellectilium* (Serv.). *Nauphoeta cinerea* (Oliv.) is a "semi-domestic." The *Periplanetas* deposit their capsules within a day or two of formation. *S. supellectilium* carries them for 1 to 8 days, and *B. germanica* carries them until the eggs are ready to hatch. *N. cinerea* is viviparous.

The maximum number of ovipositions recorded was :—*P. australasiae* (31), *P. americana* (68), *P. ignota* (30), *B. germanica* (5), *S. supellectilium* (25) and *N. cinerea* (4).

The usual numbers of eggs in a capsule were :—*P. australasiae* (26), *P. americana* (16), *P. ignota* (24), *B. germanica* (40), *S. supellectilium* (18) and *N. cinerea* (40).

The rate of development of all stages was greatly influenced by temperature, but there was also considerable variation in the rate of nymphal development among siblings.

The incubation periods varied from 39 to 160 days for *P. australasiae* ; 39 to 99 days for *P. americana* ; 49 to 91 days for *P. ignota* ; 24 to 42 days for *B. germanica* ; 63 to 156 days for *S. supellectilium*.

The nymphal periods varied as follows :—*P. australasiae* 134–596 days, *P. americana* 134–813 days, *P. ignota* 110–327 days, *B. germanica* 49–212 days, *S. supellectilium* 90–355 days, *N. cinerea* 107–470 days.

The maximum life-spans recorded were :—*P. australasiae* 937 days, *P. americana* 1,502 days, *P. ignota* 732 days, *B. germanica* 384 days, *S. supellectilium* 667 days, *N. cinerea* 1,185 days.

The egg-to-egg cycles of the *Periplanetas* and *N. cinerea* cover about a whole year. Two to three generations of *B. germanica* could be bred each year and about two of *S. supellectilium*.

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Vol. LXIII. No. 3.

STUDIES OF THE LIFE HISTORIES OF SOME QUEENSLAND BLATTIDAE (ORTHOPTERA).

Part 2. Some Native Species.

By Pauline Pope, Queensland Institute of Medical Research.

(With 3 Text-figures and Plate I.)

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INTRODUCTION.

While engaged on a study of the domestic species of cockroaches common in Brisbane, interest was aroused in the numerous native species, none of which appear to have been studied previously. Some of these bred well in captivity, others proved less adaptable. Among the former were species of the genus *Methana* (subfamily Blattinae) and some species of *Ellipsidion*, and *Megamareta* (belonging to the subfamily Ectobiinae). Descriptions of the different stages and accounts of the life history of three species of *Methana*, two of *Ellipsidion* and one each of *Balta* and *Megamareta* are given. One new species of *Methana* is described.

A. THREE SPECIES OF METHANA STAL.

The three species of *Methana* studied were *M. curvigera* (Walk.), *M. marginalis* (Sauss.) and *M. caneae* n. sp.

Most species of *Methana* have fully developed tegmina and wings extending beyond the tip of the abdomen, but in several they are abbreviated. This genus has been recorded from Australia, New Guinea and Borneo, and is characterised by the supra-anal lamina in the male being quadrate, margins not serrate, and in the female triangular, apex emarginate; pronotum anteriorly parabolic, posteriorly very obtusely angled; posterior metatarsus about equal in length to remaining joints, biseriately spined beneath, its pulvillus apical; remaining tarsal segments with large pulvilli, not spined beneath; tarsal claws asymmetrical. The females have the typical blattine bivalvular type of subgenital plate and that of the male bears a pair of unsegmented styles. The cerci are long and acuminate.

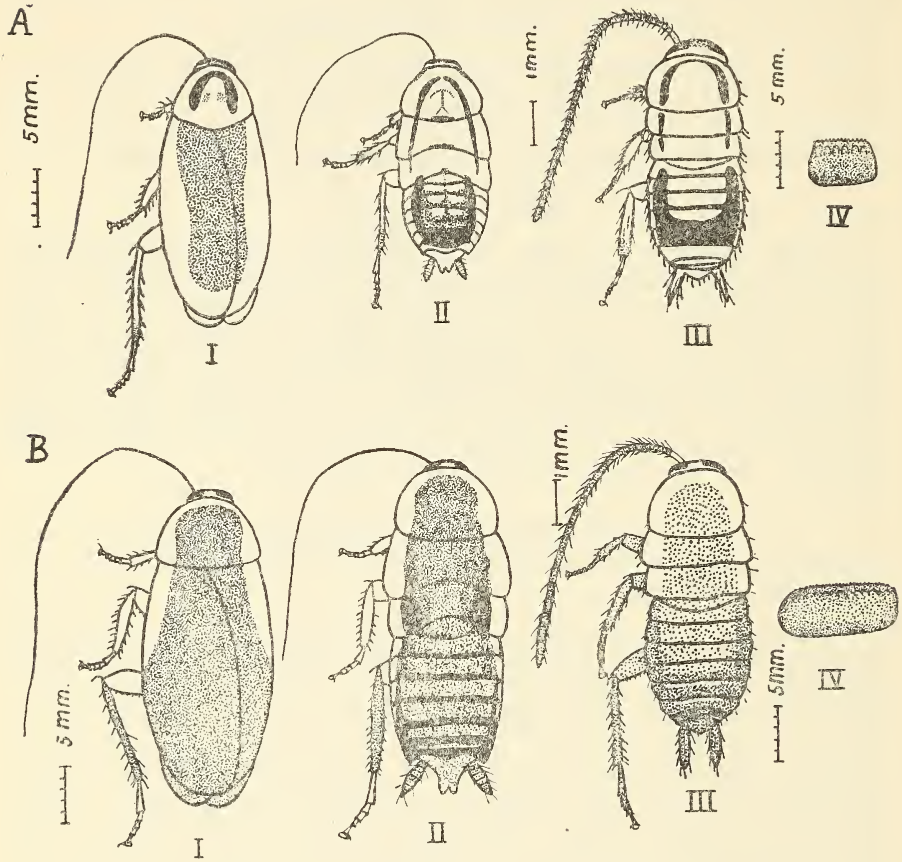
The favourite haunt of these species is under the loose bark of trees or logs. Many specimens of *curvigera* were found in wattle trees. In the strong sunlight they hid in curled up leaves. Their egg cases were found attached to the underside of loose bark or leaves.

In laboratory colonies they were easily bred. Leaves and pieces of bark were added to their rearing jars. They usually endeavoured to conceal their egg-capsules with sand, food particles, or minute pieces of chewed bark. Their regular diet was the same as that of the domestic species (Pope, 1953). All the native species were reared at room temperature.

1. METHANA CURVIGERA (Walker, 1868).

Tepper (1893) cites Walker's habitat of this species as Moreton Bay, Queensland. Specimens have been collected at Fraser Island and at Maryborough on the adjacent mainland.

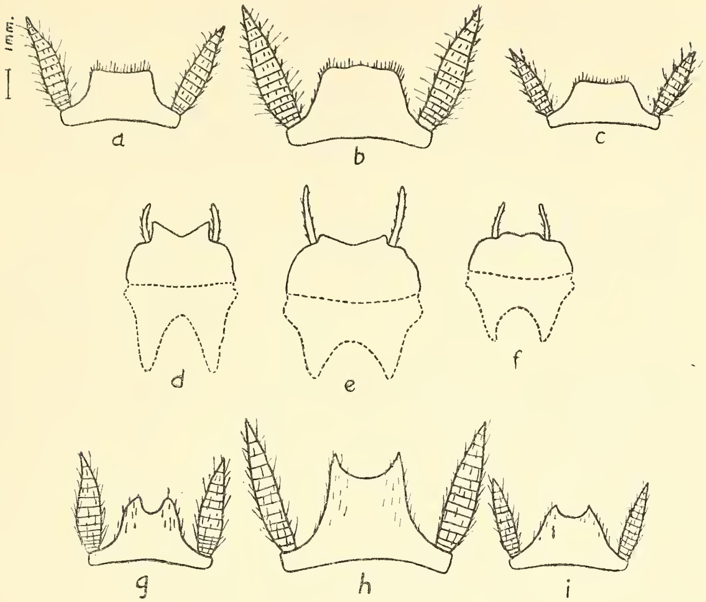
This pale species has quite distinctive markings in black and reddish-brown. The wide, pale or transparent margin around the whole insect is a striking feature of both adults and nymphs. It adapted itself very well to our laboratory conditions and was always very lively.



Text-fig. 1. A. *M. curvigera* (Walk.), B. *M. marginalis* (Sauss.). I, male adult; II, large nymph; III, newly hatched nymph (mounted specimen); IV, egg-capsule. Adults, large nymphs and egg-capsules are drawn to same scale. Newly hatched nymphs are greatly enlarged.

(a) Description of Stages.

ADULT (Text-fig. 1 AI). Head pale cream with dark, transverse interocular band on vertex and pale inconspicuous ocelliform spots; interocular width less than interantennal. Long, light brown antennae. Pronotum pale, translucent, with dark brown ∩-shaped band around lateral and anterior portions of disc, the band being sometimes interrupted in the mid line anteriorly. Left tegmen with wide colourless band along anterior margin to apex, remainder reddish-brown. Right tegmen similar except that the portion overlapped by the left tegmen is paler. Wings transparent except for white markings in the radial areas and a brownish suffusion basally over the branches of the median vein. Abdominal tergites pale, developing medium brown tinges and dark brown lateral marks towards



Text-fig. 2. Genital plates of three species of *Methana*. Male supra-anal : *a*, *curvigera* : *b*, *marginalis* : *c*, *caneae*. Male subgenital : *d*, *curvigera* : *e*, *marginalis* : *f*, *caneae*. Female supra-anal : *g*, *curvigera* : *h*, *marginalis* : *i*, *caneae*.

7th, which is sharply backwardly produced; 8th to 10th pale, last with small dark marks. Abdominal sternites reddish-brown darkening laterally, but extreme lateral margins pale. Legs pale, dark spines, slight darkening at tip of hind tibia, large arolia. Cerci pale yellowish-brown.

Total length :	♂ 22-23 mm.,	♀ 20-24 mm.
Tegmina length :	♂ 17-18 mm.,	♀ 16-18 mm.
Pronotum width :	♂ 7·5-8·5 mm.,	♀ 8-8·5 mm.

LARGE NYMPH (Text-fig. 1 AII). Thoracic tergites pale, almost transparent laterally, outline of body marked by brownish-black line. Posterior margins of pronotum and mesonotum dark brown, trace on metanotum. Pronotum narrowly edged with brown. Dorsum of abdomen with broad white lateral and posterior margins. Anterior tergites pale in centre, becoming reddish-brown then black sub-laterally and posteriorly. Abdominal sternites reddish-brown darkening laterally, but with extreme lateral margins white.

NEWLY HATCHED NYMPH (Text-fig. 1 AIII). Yellow head, dark vertex, black antennae. Yellow thoracic tergites, black line marking outline of body, translucent edges. First abdominal tergite yellow, 2nd to 6th dark laterally and posteriorly, the dark posterior band widening towards apex, remainder yellow. Abdominal sternites brownish-yellow. Tarsi and tibiae with slight apical darkening, arolia present. Body length : 3·5-4 mm. Antennae length : 6 mm.

EGG CAPSULE (Text-fig. 1 AIV). Orange, shiny, mediolateral brown dots (sometimes smudges) giving squared effect. Usually contains 12 eggs, range 8-14. Length : 6-7 mm. Depth : 4 mm.

(b) Life History.

(i.) THE INCUBATION PERIOD varied from about 5 weeks in midsummer to 8-9 weeks in midwinter.

(ii.) NYMPHAL DEVELOPMENT. Males usually appeared first in a colony, but sometimes males and females appeared simultaneously. The minimum period observed was 176 days. The results obtained in 5 colonies are set out in Table I.

TABLE I.
Duration of Nymphal Development of M. curvigera.

Colony Number.	Date of Hatching.	Duration (in Days) from Hatching to Appearance of Adult.		
		Male.	Female.	Final.
253	28 Mar.	246	259	266
297	27 May	181	228	228
317	21 June	176	203	203
310	27 June	193	190	—
316	7 July	180	180	235

(iii.) EGG-LAYING. Preoviposition periods from 14 to 29 days were recorded. One female kept with several males produced 16 egg-capsules at intervals of about 8 days. The female produced the egg-capsule with the serrated ridge dorsal, she usually carried it for one or two days and then fastened it to bark or concealed it in the food.

(iv.) LONGEVITY. The total life span of males ranged from 404 to 505 days, mean 451 days (7 observations). For females the range was 264 to 515 days, mean 419 days (8 observations).

2. METHANA MARGINALIS (Saussure, 1864).

This large, brown species with fully developed tegmina and wings in both sexes has a flavid margin on the anterior and lateral margins of the pronotum, extending to the radial margin of the tegmina.

Tepper (1893) gives Walker's habitat of this species as "Queensland, West Australia." It has been reported from North Queensland. Our specimens were taken in South Queensland. It has sometimes been reported as entering houses, but all our specimens were collected in the field.

(a) Description of Stages.

ADULT (Text-fig. 1 BI). Light coloured head, dark vertical marking on frons not joining dark transverse bar on vertex, interocular width considerably less than interantennal, white ocelliform spots, long brown antennae. Rich shiny reddish-brown pronotum and tegmina, white band around anterior and lateral edges of pronotum, white humeral streak on tegmina extending beyond the level of the anal area. That portion of right tegmen which is overlapped by the left is distinctly paler than the remainder. Anterior part of wings light brown, posterior part transparent with brown axillary veins. Abdominal tergites medium brown darkening laterally and posteriorly and towards apex of abdomen, 2nd to 4th with pale basal spots on the lateral margins, 3rd to 7th backwardly produced, most conspicuously so in 6th and 7th. Abdominal sternites dark reddish-brown, shiny, 1st to 3rd with pale lateral markings. Legs pale with brown edges and spines. Hind tibiae brown. Cerci brown, considerably exceeding supra-anal lamina. The genital plates of both sexes are shown in text-fig. 2. Measurements of both sexes :—

Total length :	25-29 mm.
Tegmina length :	20-23 mm.
Pronotum width :	10-13 mm.

LARGE NYMPH (Text-fig. 1BII). Thoracic tergites reddish-brown with white lateral margins joining anteriorly on pronotum, blackish wing pads. Abdominal tergites reddish-brown with black posterior margins, 2nd to 7th backwardly produced, 2nd to 5th with light lateral edges ; abdominal sternites light reddish-brown with pale markings laterally and very narrow dark posterior margins.

NEWLY HATCHED NYMPH (Text-fig. 1 BIII). Face dark brown, vertex yellow, orange antennal sockets, black antennae with paler bases. Light brown thoracic tergites with translucent edges and the dark outline of the body visible. Slightly darker brown abdominal tergites with lateral darkening, 6th to 7th with dark posterior margins. Abdominal sternites light brown with lateral darkening. Dark brownish-black legs with orange spines, large arolia. Cerci yellow at base, tip black. Total length : 4-5 mm. Antennae length: 7·5 mm.

EGG-CAPSULE (Text-fig. 1 BIV). Very large, dull orange brown colour at sides ; dark brown, flat base ; serrated ridge. Usually contains 26 eggs, range 24 to 30. Length : 11-13 mm. Depth : 4-5 mm.

(b) LIFE HISTORY.

(i.) THE INCUBATION PERIOD varied from about 5 weeks in midsummer to 8 weeks in midwinter. The number of nymphs derived from one egg-capsule varied from 12 to 26, average 18.

(ii.) NYMPHAL DEVELOPMENT seemed less affected by temperature than might be expected. Nymphs born in late summer and developing during winter reached maturity in approximately the same time as early summer nymphs. The results of observations on six colonies are set out in Table II.

TABLE II.
DURATION OF NYMPHAL DEVELOPMENT IN M. MARGINALIS.

Colony Number.	Date of Hatching.	Duration (in Days) from Hatching to Adult.		
		Male.	Female.	Final.
237	8 Mar.	231	260	379
352	14 Nov.	256	239	274
358	17 Nov.	250	243	258
361	21 Nov.	183	246	294
372	12 Dec.	225	270	309
384	19 Dec.	221	241	—

(iii.) EGG-LAYING. The minimum preoviposition period observed was 10 days, but in most colonies it was much longer, ranging from 3 to 6 weeks. The female of a pair of adults, which were captured in the field, deposited 11 egg-capsules in 57 days, i.e. approximately one every 5 days. Observations on 2 isolated pairs were made. The females deposited 9 and 16 egg-capsules respectively, at intervals ranging from 5 to 14 days. A female usually carried her large egg-capsule for 1 to 2 days. It was usually fastened to bark and covered lightly with debris.

(iv.) LONGEVITY. Six males were observed to live from 339 to 473 days, mean 390 days; five females lived from 275 to 589 days, mean 453 days. These figures refer to the total life-span, i.e. hatching until death.

3. METHANA CANEAE n. sp.

An undescribed species was found on Fraser Island, Queensland. Specimens were obtained from under loose bark on a dead, upright tree.

It differs from *marginalis* (Sauss.) in (a) its smaller size, (b) the abbreviated tegmina and wings, and (c) wider interocular space; and from *parva* Shaw in (a) the flavid humeral streak extending beyond the level of the anal area, (b) the form of subgenital plate of the male, and (c) vertical band on frons not joining that on vertex. This species has been named in honour of Miss Helen Cane of the Division of Entomology, Commonwealth Scientific and Industrial Research Organisation, Canberra, who is at present working on a systematic review of Australian Blattidae and to whom we are indebted for assistance in identifying native species.

(a) DESCRIPTION OF STAGES.

ADULT (Plate I, fig. 1. b, c). Pale head, dark vertical bar on frons not joining dark transverse band on vertex, very inconspicuous ocelliform spots; interocular width only slightly less than interantennal width and approximately twice ocular depth. Pronotum shiny, dark brown with a wide white band around the anterior and lateral margins and a very narrow dark line on extreme edge. Reddish-brown tegmina with pale humeral streak fading away just before it reaches the apex; portion of right tegmen which is overlapped by left is distinctly paler than the remainder; wings with anterior portion brown and posterior portion colourless with brown axillary veins; tegmina and wings extending to 6th abdominal tergite. Abdominal tergites dark brown, 2nd to 5th with pale spots laterally, 2nd to 7th backwardly produced. Abdominal sternites reddish-brown darkening laterally and posteriorly. Dark cerci exceeding supra-anal lamina. Pale coxae with dark stripe, pale femora, brown tibiae, dark tarsi; tarsal claws very asymmetrical. The genital plates of both sexes are shown in text-fig. 2.

Total length:	♂ 19-22 mm.,	♀ 20-24 mm.
Tegmina length:	♂ 11·5-13 mm.,	♀ 12·5-13 mm.
Pronotum width:	♂ 8-9 mm.,	♀ 8·5-9 mm.

LARGE NYMPH (Plate I, fig. 1a). Light brown head, brown band on front joining that on vertex, light brown antennae. Light, reddish-brown thoracic tergites with wide, translucent margins, which are narrowly edged with brown. First abdominal tergite reddish-brown, 2nd to 5th reddish-brown in centre, dark brown laterally, margins of 2nd to 5th pale, remaining segments dark brown. Abdominal sternites reddish-brown, small dark lateral dots. Pale coxae with dark streaks, tibiae light brown, darkening towards tarsi. Reddish-brown cerci.

NEWLY HATCHED NYMPH (Plate I, fig. 1e). Yellowish head, dark brown antennae. Yellow thoracic tergites, 2nd to 3rd with pale orange posterior margins. Abdominal tergites yellow with orange posterior margins, 6th with brown lateral dots. Orange abdominal sternites darkening very slightly laterally. Yellow coxae, legs darkening slightly from femora to tibiae, arolia present. Yellow cerci with dark tips. Total length: 3 mm. Antennae: 5 mm.

EGG-CAPSULE (Plate I, fig. 1d). Orange-yellow with irregular medio-lateral brown markings, flat base giving squarish effect. Serrated ridge. Usually contains 22 eggs. Length : 9-10 mm. Depth : 4 mm.

DISTRIBUTION. Fraser Island, Queensland, (Feb.), type locality.

TAXONOMIC NOTES. Holotype male, allotype female, morphotype nymphs and egg-capsule, bred in laboratory from adults collected at Fraser Island, Q.; in collection of the Division of Entomology, C.S.I.R.O., Canberra.

(b) LIFE HISTORY.

(i.) THE INCUBATION PERIOD varied from 4½-5 weeks in midsummer to 7-8 weeks in winter. The number of nymphs hatching from one egg-capsule varied from 12 to 22, average 16.

(ii.) NYMPHAL DEVELOPMENT. The most rapid development occurred in a colony set up in early spring, adults of both sexes appearing by the 20th week. The results obtained from six colonies are set out in Table III.

TABLE III.
DURATION OF NYMPHAL DEVELOPMENT IN M. CANEAE.

Colony Number.	Date of Hatching.	Duration (in Days) from Hatching to Adult.		
		Male.	Female.	Final.
252	28 Mar.	200	200	205
270	11 Apr.	203	213	227
278	19 Apr.	224	202	—
284	22 Apr.	195	195	—
290	29 Apr.	188	200	—
325	25 Aug.	139	132	—

(iii.) EGG-LAYING. The preoviposition period varied from 12 to 26 days. The female usually carried the egg-capsule for 1-2 days and fastened it to bark. Two colonies containing 2 and 3 pairs were kept under observation. The former produced 69, the latter 79 egg-capsules. The period of reproductive activity lasted about one year. Egg-laying continued throughout the winter, though there was definite falling off in production in April, May and June. In each of these colonies females survived considerably longer than the males, and the last few egg-capsules produced were infertile.

(iv.) LONGEVITY. The total life-span of 5 males ranged from 344 to 568 days (mean 472 days), that of 5 females ranged from 562 to 702 days (mean 622 days).

B. SOME ECTOBIINE SPECIES.

The species belonging to the subfamily Ectobiinae which were studied were *Ellipsidion affine* Hebard, *E. australe* Sauss., *Balta scripta* (Shelford) and *Megamareta verticalis* Hebard. *E. affine* and *E. australe* were collected in trees near Brisbane, *B. scripta* on Fraser Island and near Brisbane, and *M. verticalis* at Gordonvale (North Queensland).

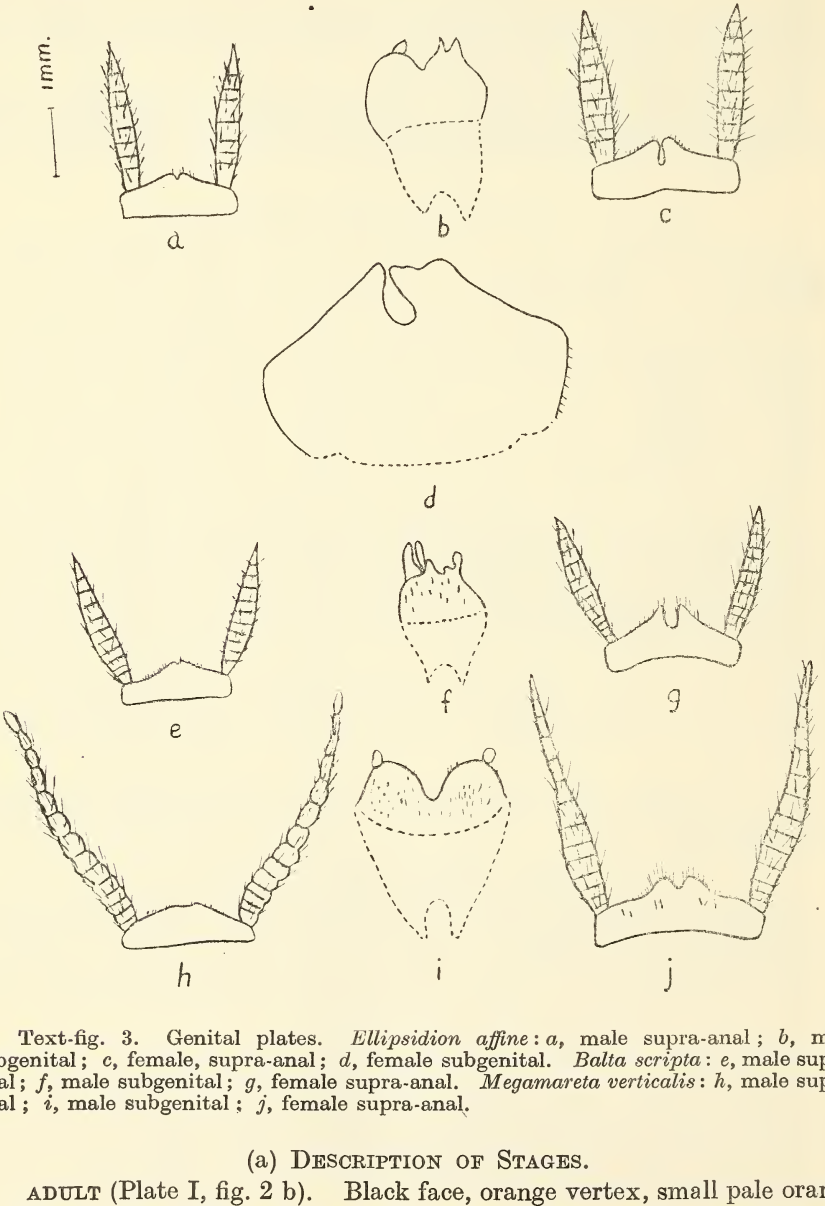
All these species have the following characters in common :—(i) female subgenital plate not of the valvular (blattine) type; (ii) anterior femora with antero-ventral margin lacking heavy spines before the row of piliform spines and with one or two terminal spines; (iii) median and posterior femora with ventral margins armed with spines; (iv) tarsal claws simple and decidedly asymmetrical.

In *Ellipsidion* and *Balta* the tegminal discoidal sectors are oblique, while in *Megamareta* they are longitudinal.

1. ELLIPSIDION AFFINE Hebard, 1943.

E. affine is a small species which has a black abdomen, the lateral and caudal margins of abdominal sternites being edged with white. These are the markings characteristic of the genus. Both sexes have fully developed tegmina and wings.

All the young hatching from one capsule were set up as one colony. This proved rather awkward because in a colony there often appeared a very great interval between the first moults to adult and the last.



Text-fig. 3. Genital plates. *Ellipsidion affine*: *a*, male supra-anal; *b*, male subgenital; *c*, female, supra-anal; *d*, female subgenital. *Balta scripta*: *e*, male supra-anal; *f*, male subgenital; *g*, female supra-anal. *Megamareta verticalis*: *h*, male supra-anal; *i*, male subgenital; *j*, female supra-anal.

(a) Description of Stages.

ADULT (Plate I, fig. 2 b). Black face, orange vertex, small pale orange ocelliform spots, black antennae with wider and very hairy basal half and orange distal half; interocular width greater than interantennal. Orange pronotum with translucent margins, darker over body, sometimes with faint dark marks on pronotal disk. Orange tegmina with black bases and slightly black apices, exposed part with checkered effect; orange wings with wide, black border extending from apical to anal area. Some black thoracic sternal plates; abdominal sternites black, 3rd to 6th with definite white lateral and posterior margins, faintly marked on 2nd, 7th white laterally, 8th and 9th wholly black. Orange cerci with black bases, considerably exceeding supra-anal lamina. Black coxae with definite white stripe on posterior margin, orange legs, apical halves of femora black, tarsi dark (except for slight orange tinge on posterior metatarsus). The genital plates of both sexes are shown in text-fig. 3. Measurements for both sexes are:

Total length: 11-13·5 mm.
Tegmina length: 9·5-11·5 mm.
Pronotum width: 4·5-5 mm.

LARGE NYMPH (Plate I, fig. 2 a). Black pronotal disk bordered laterally with orange, white posterior margin, transparent lateral margin. Mesonotum and metanotum black with orange translucent lateral margins and white posterior margins. Abdominal tergites 1st and 2nd rounded, 3rd to 7th with postero-lateral angles backwardly produced; first five tergites with white dots on posterior margin and a transverse white line just anterior to the row of dots, 6th and 7th with posterior margin white and two median white dots; 8th and 9th black with white posterior margin; 10th wholly black. Some dark thoracic sternal plates; abdominal sternites black, 1st five with white lateral and posterior margins, 6th with white lateral margins. Black coxae with white stripe, orange trochanter, black femora with orange tinges, tibiae orange in centre, remainder black, dark tarsi, large arolia.

NEWLY HATCHED NYMPH. Dark brown head, translucent antennae darker at tips; interocular width greater than interantennal. Dark brown pronotum; golden brown mesonotum and metanotum; all thoracic tergites with translucent margins. Dark brown abdominal tergites. Medium brown abdominal sternites. Golden-brown cerci. Dark brown legs with transparent tarsi. Styles present in both sexes. Body length, 1·5-2 mm.; antennae length, 1·5 mm.; pronotum width, 1 mm.

EGG CAPSULE (Plate I, fig. 2c). Cream with brown medio-lateral dots, sometimes slightly darker below these; dark brown base. Contains 30-32 eggs. Length, 6 mm.; depth, 2·5 mm.

(b) LIFE HISTORY.

(i.) INCUBATION PERIOD. In the summer months the egg incubation period was usually 25 days while in the winter it was twice as long.

(ii.) PERIOD OF NYMPHAL DEVELOPMENT. As our series began in the middle of the summer season, the nymphs which did not reach maturity quickly had a very long nymphal period extended by the winter snap. The minimum period from hatching to the appearance of adults was 59 days, the majority, however, required 10 weeks to complete their development. Nymphs hatched in February did not become adult until August, average period 175 days. In most colonies there was a considerable lag between the appearance of the first and last adults, for three colonies for which records were kept, it varied from 5 to 35 weeks.

(iii.) COPULATION. Apparently daylight does not disturb this species very much, because the females could be seen depositing egg-cases, and pairs could be seen preparing to copulate and actually copulating. On several occasions the whole process was observed. The pair obviously appeared interested in each other, and rushed backwards and forwards frantically waving their antennae. The male walked around with his wings upright and his body arched so that the tip dragged over whatever he crawled on. At the same time the cerci pointed inwards and downwards together in the same plane as the abdomen. The male stood right in front of the female with the tip of his abdomen under her head. Then he poked his body under hers, and, as the female crawled on to his back, she appeared to wipe his tergites with her palps. When the tip of the male's abdomen reached that of the female he grasped her genitalia. Almost as soon as they contacted they swung round end-to-end in a flashing movement and then copulation took place. If the male failed to grasp the female, the pair would break away and start again. From the literature it appears that copulation in some cockroaches is a very speedy process. However, in the laboratory we have observed pairs of *E. affine in copulo* for periods as long as an hour. The female dragged the male in whatever direction she chose while the pair was in copulation.

This species copulated very frequently. A short observation on one pair is quite indicative.

Date.	Action of Pair.
6 XII. 48 ..	Pair copulating
13 XII. 48 ..	Female depositing
16 XII. 48 ..	Pair copulating
21 XII. 48 ..	Female depositing
22 XII. 48 ..	Pair copulating
23 XII. 48 ..	Female depositing
27 XII. 48 ..	Female depositing
1 I. 49 ..	Pair copulating
3 I. 49 ..	Female depositing
6 I. 49 ..	Female depositing

Five days after a pair matured they copulated, and 9 days after this the female was carrying an egg case. Actually in our colonies the preoviposition period varied from 14 to 30 days. The egg-capsule was produced with the serrated ridge dorsal, it was usually only carried for a day and then fastened on to a stem or the underside of a leaf.

(iv.) EGG-LAYING CAPACITY. The total egg-laying capacity was not determined, but one female laid 8 egg-capsules in 6 weeks, the average interval being 6 days, another laid 5 in 44 days. The egg-to-egg cycle is measured from the deposition of one capsule through until the nymphs hatching from it mature and deposit their first capsule. In the summer season it was as short as 113 days, while cycles in the winter season were extended to well over 200 days. It is possible for two generations of this species to be bred each year.

2. ELLIPSIDION AUSTRALE (Saussure, 1864).

This species has the characteristic markings of the genus i.e. black sternites edged with white. It is larger than *E. affine*, being about 19 mm. long and 6 mm. wide (at level of pronotum). The general colouration is a darker shade of orange and the black markings on the tegmina and wings are more pronounced. The pronotum is black with a yellow margin. It is an arboreal species like *E. affine*; and the nymphal stages of these two species are very similar. (Plate I, fig. 3 a-c).

Life History.

The incubation period varied from 3-4 weeks in midsummer to 6-7 weeks in midwinter. The number of eggs per egg-capsule was usually 32.

The nymphal period for nymphs hatching in early summer was about 18 weeks, those hatching in later summer required 32 weeks.

The preoviposition period was about 3 weeks. Females produced the egg-capsule with the serrated ridge dorsal and fastened it to bark or leaves, but did not attempt to conceal it. One female adult, collected in the field, laid 8 egg-capsules in 5 weeks, the average interval being 5 days.

Some insects were observed to live from 312 to 441 days, i.e. from hatching to death.

3. BALTA SCRIPTA (Shelford, 1911).

Balta scripta is a small, greyish-brown speckled cockroach. It was a very difficult species to handle in the laboratory. The adults were extremely lively, and the newly hatched nymphs very small and practically colourless. The small, light brown egg-cases were usually well concealed by the female either in the food, or sand in the bottom of the jar, and they were always extremely difficult to find.

(a) Description of Stages.

ADULT (Plate I, fig. 4 b). Light brown head; dark transverse interocular band with cream transverse band immediately below it, and another dark transverse band immediately below this again; interocular width less than interantennal; light brown antennae darkening towards tip. Pronotum light brown with transparent lateral margins and a symmetric design in dark brown lines and dots on the disk. Tegmina and wings fully developed in both sexes. Tegmina with checkered effect, transparent edge along lateral margin (when folded in repose). Wings with distal end of costal veins thickened. Abdomen light brown. Light brown cerci projecting considerably beyond supra-anal lamina. Pale yellowish-brown legs. The male subgenital plate is very asymmetrical (Text-fig. 3 f), that of the female simple, ample and slightly emarginate on the free margin. The supra-anal plates are shown in text-fig. 3 e, g.

Total length :	♂ 10·5 mm.,	♀ 9·5 mm.
Tegmina length :	♂ 9 mm.,	♀ 8 mm.
Pronotum width :	♂ 3·3 mm.,	♀ 3·3 mm.

LARGE NYMPH (Plate I, fig. 4 a). Pale head; dark transverse interocular band with pale transverse band below it and another dark transverse band below this, and then an interantennal transverse row of dots. Pronotum widest posteriorly, translucent lateral margins, pale pronotal disk with symmetric design in dark brown lines and dots. Thoracic and abdominal tergites pale, symmetrically marked with dark brown lines and dots. Abdominal sternites pale with dark brown markings. Cerci pale with dark brown marks, considerably exceeding supra-anal lamina. Pale legs, dark stripe at base of coxae, slight darkening at base of spines.

NEWLY HATCHED LARVA. Pale cream transparent head, body and appendages; large arolia. Total length: 1·3 mm. Pronotum width: 0·73 mm.

EGG CAPSULE (Plate I, fig. 4 c). Light brown, concolorous; length of serrated ridge greater than basal length. Usually contains about 16 eggs. Length: 3 mm. Depth: 2 mm.

(b) LIFE HISTORY.

The incubation period was 28-30 days for eggs laid in January and February. The nymphs energing from a capsule in July (that is, about midwinter) matured 142-148 days later, while those emerging in February matured in 230 days. The longevity of two males was 219 and 231, while the intervals between their final moult and their death were 71 and 83 days. Another male lived 146 days as an adult. Two females which produced 7 and 8 egg capsules lived for 68 and 181 days respectively as adults. The longevity of the first female was 216 days from hatching.

4. MEGAMARETA VERTICALIS Hebard, 1943.

This is a relatively large, broad species (in comparison with other Ectobiinae), uniformly pale yellow in colour. It adapted itself quite easily to our laboratory conditions, and was probably the liveliest and most prolific of the ectobiine species we bred.

(a) DESCRIPTION OF STAGES.

ADULT (Plate I, fig. 5b). Pale yellow head and body. Interocular width less than interantennal; white ocelliform spots; pale antennae darkening slightly towards tip; darker brown vertical band on face, often expanding near ocelliform spots to become almost T-shaped; brown interocular band. Pronotum with transparent lateral margins. Tegmina with transparent humeral streak, wings with distal ends of costal veins slightly thickened. Pale cerci projecting considerably beyond supra-anal lamina. Legs uniformly pale yellow. The genital plates of both sexes (except the female subgenital, which is simple and ample) are shown in text-fig. 3 h-j. The measurements of both sexes are as follows:—

Total length:	13·5-15 mm.
Tegmina length:	12-13 mm.
Pronotum width:	5 mm.

LARGE NYMPH (Plate I, fig. 5 a). Pale yellow head and body. Thoracic tergites with broad transparent margins; all with two small brown dots posteriorly. Pale yellow abdomen; 1st to 5th abdominal tergites with row of small brown dots on posterior margin, 6th to 10th with small dark markings on lateral margins. Pale cerci with slightly dark bases, considerably exceeding supra-anal lamina. Pale, almost transparent legs.

NEWLY HATCHED NYMPH. Very pale head and body with almost transparent appendages. Very wide interocular space. Thoracic tergites each with two dots posteriorly. Mottled cerci. Large arolia. Total length: 2 mm.

EGG CAPSULE (Plate I, fig. 5 c). Very dark brown, smooth, not shiny, very narrow; compartments do not show up distinctly; wider at ridge than base; usually contains 30-36 eggs. Length, 6-7 mm.; depth, 3 mm.

(b) LIFE HISTORY.

During midsummer the incubation period ranged from 34 to 38 days, in early and late summer it covered 40 to 50 days and in midwinter 63 to 76 days.

Nymphs emerging in the early summer matured in 90 to 130 days.

The preoviposition period varied from 7 to 17 days. In a colony containing four females kept under observation for 9 months over 70 egg-capsules were produced. The female of the original pair was already an adult of unknown age when our laboratory series began. She produced 10 egg-capsules in 84 days, at intervals ranging from 3 to 22 days. In the gravid female the abdomen became distinctly green just before she produced an egg-capsule.

The total life-span ranged from 257 to 408 days, mean 344 days, for 11 males ; and 265 to 424 days, mean 350 days, for 14 females.

Acknowledgments.—I wish to thank Miss H. Cane of the Division of Entomology, C.S.I.R.O., Canberra, for identifying these native species ; and Dr. M. J. Mackerras and Mr. R. Domrow of this Institute for assistance in the work and in the preparation of the manuscript.

SUMMARY.

One new species, *Methana caneae* n. sp. is described together with its life-history. Brief descriptions and life-histories are given of *Methana curvigera* (Walk.), *M. marginalis* Stal, *Ellipsidion affine* Hebard, *E. australe* (Sauss.), *Balta scripta* (Shelford) and *Megamareta verticalis* Hebard.

The periods observed for egg incubation, nymphal development and maximum life span respectively are as follows :—

M. curvigera :	5 to 9 weeks ;	25 to 38 weeks ;	515 days.
M. marginalis :	5 to 8 weeks ;	26 to 44 weeks ;	589 days.
M. caneae :	4½ to 8 weeks ;	19 to 32 weeks ;	702 days.
E. affine :	3½ to 7 weeks ;	8½ to 45 weeks ;	315 days.
E. australe :	3 to 7 weeks ;	18 to 32 weeks ;	441 days.
B. scripta :	4 weeks (summer) ;	20 to 33 weeks ;	230 days.
M. verticalis :	5 to 11 weeks ;	13 weeks (summer) ;	424 days.

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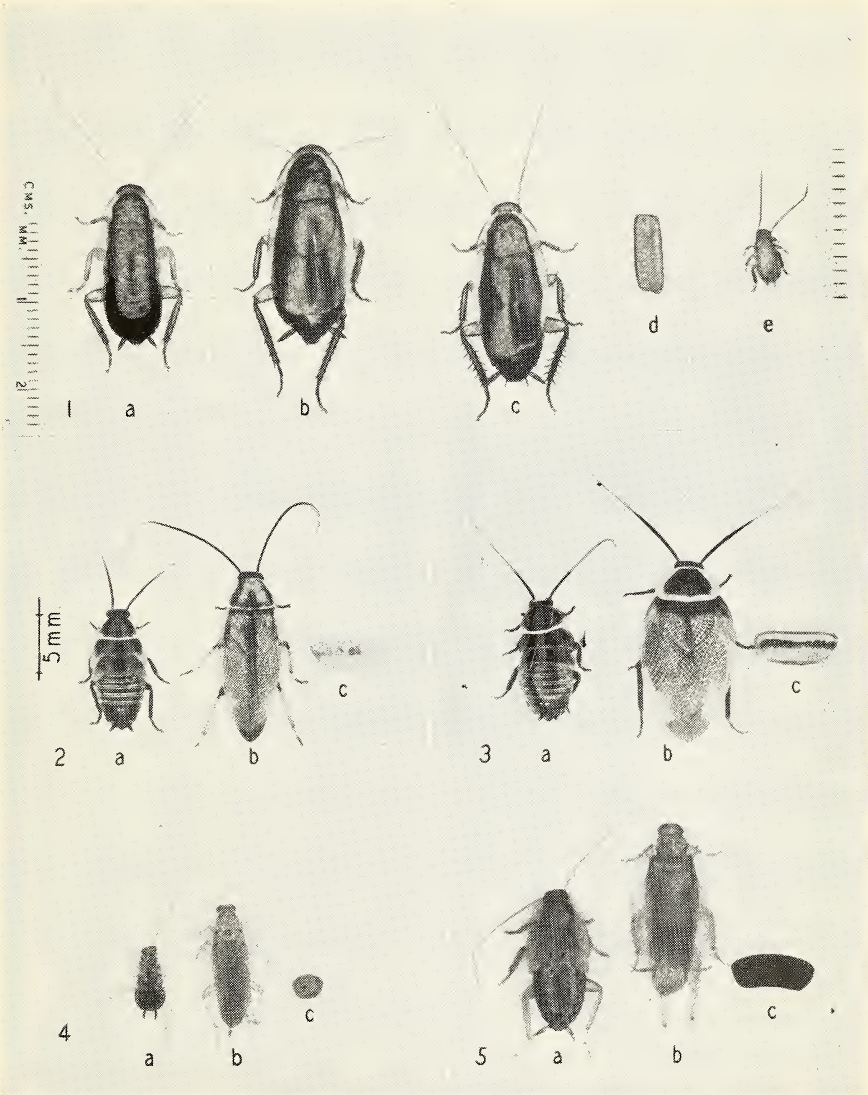
EXPLANATION OF PLATE I.

Fig. 1. *Methana caneae* : a, large nymph ; b, female adult ; c, male adult ; d, egg-capsule; e, newly hatched nymph. Fig. 2. *Ellipsidion affine*. Fig. 3, *E. australe*. Fig. 4. *Balta scripta*. Fig. 5. *Megamareta verticalis* : a, large nymph ; b, adult ; c, egg-capsule. Figs. 1 a-d are to same scale ; scale beside 1 e is in mm. ; figs. 2-5 are to the same scale.

Plate I.



Vol. LXIII. No. 4.

PARASITES OF THE BANDICOOT, ISOODON OBESULUS.

By I. M. Mackerras, M. J. Mackerras and D. F. Sandars,* Queensland Institute of Medical Research.

(*Received 30th July, 1951; issued separately 6th July, 1953.*)

A considerable number of parasites from bandicoots in south-east Queensland has been collected during the past two years. Several of the records are new, and it has been thought worth while to bring them all together in this preliminary list, even though some of the identifications are incomplete.

We are indebted to Dr. E. H. Derrick of this Institute for referring certain species to us.

PROTOZOA.

Trypanosoma sp.: Found in the blood. There are no previous records in Australian marsupials, but a large trypanosome has been found in the platypus in Tasmania.

Haemogregarina ?peramelis Welsh and Dalyell: Described in 1910 from *Perameles nasuta*; apparently this is the first record since then. Our material does not agree completely with the original description.

Theileria sp.: Species of *Theileria* are well known in Eutheria (*T. mutans* was introduced into Australia in cattle) and have been found in Monotremes as follows:—*T. tachyglossi* Priestley in *Tachyglossus aculeatus*, and *Theileria* sp. in *Ornithorhynchus anatinus* (Duncan, personal communication); they have not previously been recorded from marsupials.

Klossiella sp.: Found in the kidney of bandicoots in Brisbane by Derrick and Smith (personal communication).

Encephalitozoon sp.: This is an obscure genus which has not been recorded previously from marsupials. An infection was found first in mice inoculated from a bandicoot and later confirmed by finding a single group of parasites in sections of the brain of the bandicoot (E. H. Derrick, personal communication).

Sarcocystis sp.: Found in voluntary muscle of the bodywall. This genus was recorded by Bourne (1934) in *Bettongia*, but is not otherwise known from marsupials.

PLATYHELMINTHES.

Trematoda:

Brachylaemus similis (S. J. Johnston), syn. *Harmostomum simile*.

Platynosomum Looss (new record). The recovery of *Platynosomum* sp. appears to be the first record of a pancreatic fluke from an indigenous Australian mammal.

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* and Department of Social and Tropical Medicine, University of Queensland.

CESTODA :

Hymenolepis peramelidarum Nybelin.

Linstowia echidnae (Thompson) (recorded by other workers but not taken by us).

Linstowia semoni Zschokke (recorded by other workers but not taken by us).

ACANTHOCEPHALA.

Gigantorhynchus semoni Linstow.

NEMATODA :

CAPILLARIINAE (new record). These very slender worms were found embedded or half embedded in the oesophageal walls of the host.

Echinonema cincta (Linstow), syn. *Hoplocephalus cinctus* Linstow.

Filarinema peramelis T. H. Johnston and Mawson.

Subulura peramelis Baylis.

Trichuris peramelis Baylis.

METASTRONGYLIDAE. The first record is made of a lung worm from an Australian marsupial.

FILARIOIDEA. A new species of *Dipetalonema* was found in the subcutaneous tissue. No microfilariae were found in the blood, but on making sections of the skin they were found immediately below the Malpighian layer. The finding of microfilariae in the skin suggests relationship with *Onchocerca*, but the worm is quite distinct morphologically. The life history is still unknown. The intermediate host may be a biting insect, e.g. a mosquito or sandfly, or it may be a mite.

ECTOPARASITES.

The ectoparasites of this bandicoot are quite numerous, the following having been recorded either from *Isoodon obesulus* or *I. macrourus*. Dr. E. H. Derrick and Mr. D. J. W. Smith included many of them in their studies on Q fever, and published a list in the Annual Report of the Health and Medical Services of the State of Queensland for 1937-38.

ACARINA.

TICKS.—*Ixodes holocyclus* Neumann ; *I. tasmani* Neumann ; *I. fecialis* Warburton and Nuttall ; *Haemaphysalis humerosa* Warburton and Nuttall.

MITES.—*Heterolaelaps antipodianum* Hirst ; *Mesolaelaps australiensis* Hirst ; *M. anomalus* Hirst ; *Laelaps nuttalli* Hirst ; *Ascoschöngastia dasycerci* (Hirst) ; *A. cairnsensis* (Womersley and Heaslip) ; *A. peramelis* (Womersley) ; *A. phascogale* (Womersley and Heaslip) ; *Trombicula deliensis* Walch ; *T. minor* Berlese ; *Guntherana bipygalis* (Gunther) ; *Bdellonyssus bursa* (Berlese) ; LISTROPHORIDAE, species not yet identified.

INSECTA.

MALLOPHAGA.—*Boopia* sp.

SIPHONAPTERA.—*Acedestia chera* Jordan ; *Stephanocircus dasyuri* Skuse ; *Pygiopsylla zethi* Jordan and Rothschild ; *P. congrua* Jordan and Rothchild ; *P. hoplia* Jordan and Rothchild ; *Ctenocephalides canis* (Curtis) ; *C. felis* (Bouché).

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Vol. LXIII. No. 5.

A STUDY OF DIPHYLLOBOTHRIIDAE (CESTODA) FROM AUSTRALIAN HOSTS.

By Dorothea F. Sandars, Queensland Institute of Medical Research, and Department of Social and Tropical Medicine, University of Queensland.

(With Plates II. and III.)

(*Received 26th November,* 1951; *issued separately 6th July,* 1953.)

INTRODUCTION.

Following the recovery of numerous spargana from a local host, an investigation was undertaken to identify the adult of these parasites and determine whether laboratory animals would serve as "reservoir" hosts for the spargana.

The author would like to express appreciation for the co-operation given by Dr. M. J. Mackerras during this work; to Mr. J. Thomson and Dr. M. C. Bleakly who identified the copepods and frogs respectively, and to Mr. A. J. Bearup for many helpful suggestions and Mr. G. Thompson who carried out some of the photographic work.

PREVIOUS RECORDS OF DIPHYLLOBOTHRIIDAE IN AUSTRALIAN HOSTS.

The following records were found in a search of the available literature; those marked with an asterisk were recorded by Young (1939).

ADULTS :—

**Bothridium arcuatum* Baird, 1865, in *Python spilotes* (N. S. Wales).

**Bothridium pythonis* Blainville, 1824, in *Python spilotes* (N. S. Wales).

**Bothridium pythonis* var. *parva* Johnston, 1913, in *Varanus varius* (Queensl.).

Bothridium ornatum Maplestone and Southwell, 1923, in *Python spilotes* var. *variegatus* (Queensl.).

**Bothriocephalus marginatus* Krefft, 1871, in *Macropus* sp. (Queensl.).

**Diphyllobothrium latum* (Linné, 1758) in *Homo sapiens* (Queensl., N. S. Wales, Vict., Tas.). (See Sandars, 1951).

Diphyllobothrium latum (Linné, 1758) in *Canis familiaris* (N. S. Wales) recorded by Gordon (1939). (See Sandars, 1951).

**Diphyllobothrium parvum* (Stephens, 1908) in *Homo sapiens* (Tas.).

**Diphyllobothrium antarcticum* (Baird, 1853) in "Southern Seal" (Antarctic Ocean).

**Diphyllobothrium arctocephalinum* Johnston, 1937, in *Arctocephalus forsteri*. (S. Austr.).

**Diphyllobothrium decipiens* (Diesing, 1850) in *Dasyurus* sp. (Austr.). This record is probably incorrect. It appears as though it was originally recorded from a domestic cat and not from the native cat, *Dasyurus* sp. (See Cobbold 1879, p. 308).

**Diphyllobothrium mansoni* (Cobbold, 1882) in *Felis domestica* (Queensl.).

**Dibothriocephalus felis* (Creplin, 1825) in *Felis domestica* (Queensl., N. S. Wales and Vict.).

Diphyllobothrium erinacei (Rudolphi, 1819) in *Vulpes vulpes* (Vict.) and in *Canis familiaris* (Vict.) recorded by Pullar (1946).

According to Neveu-Lemaire (1936), *Diphyllobothrium decipiens, D. mansoni* and *Dibothriocephalus felis* are probably synonyms of *Diphyllobothrium erinacei* (Rudolphi, 1819).

Wardle, McLeod and Stewart (1947) claim that *Diphyllobothrium latum* should be *Dibothriocephalus latus* Linnaeus 1758 ; *Diphyllobothrium arctocephalinum* Johnston, 1937, should be *Cordiocephalus arctocephalinus* (Johnston, 1937) ; and that *decipiens, erinacei, felis* and *mansoni* of *Diphyllobothrium* should be included in the genus *Spirometra* (Mueller, 1937).

SPARGANA :—

Sparganum mansoni (Cobbold, 1883) three records in *Homo sapiens** (N. S. Wales).

Sparganum sp. in *Homo sapiens** (N. S. Wales) ; *Vulpes vulpes** (S. Austr.) ; *Dasyurus viverrinus** (N. S. Wales) ; *Chlamydosaurus kingii** (Queensl.) ; *Dendrophis punctualatus** (Queensl.) ; *Demansia textilis** (Queensl.) ; *Pseudechis australis** (Queensl.) ; *Pseudechis porphyriacus** (Queensl. and N. S. Wales) ; *Python spilotes** (N. S. Wales) ; *Python spilotes* var. *variegatus** (N. S. Wales and Queensl.) ; *Varanus gouldii** (Queensl.) ; *Varanus varius** (Queensl.) ; *Hyla aurea** (N. S. Wales and W. Austr.) ; *Hyla caerulea** (Queensl. and N. S. Wales) ; *Thyrsites atun** (N. S. Wales).

Bearup (1948) records the sparganum of *Diphyllobothrium erinacei* in *Acanthopis antarctica* (Heathcote, near Sydney, N. S. Wales). He reared the adults in experimental kittens and infected the following copepods with procercoids :—*Mesocyclops obsoletus* (Koch), *Cyclops australis* (King) and *Leptocyclops* sp., probably *Leptocyclops agilis* (Koch).

Pullar and McLennan (1949) record *Sparganum* sp. in the pig, *Sus scrofa* (Vict.).

Recently spargana from " wild " domestic pigs from N. S. Wales have been fed to both cats and dogs. Adult *Diphyllobothrium erinacei* were recovered (Personal communication from Dr. H. McL. Gordon).

RECORDS OF NATURALLY INFECTED HOSTS.

Spargana have been recovered from the following hosts, which were taken in the greater Brisbane area :—

(*a*) *Natrix mairii* Gray. Fresh-water Snake.
(*b*) *Pseudechis porphyriacus* Shaw. Red-bellied Black Snake.
(*c*) *Hyla caerulea* White. Green Tree-Frog.

In one specimen of *Natrix mairii*, spargana were found lying close to the muscles on the dorsal side of the body cavity and smaller forms occurred in the fat around the gut. Another specimen of *Natrix mairii* was very heavily infected with spargana which occurred between the skin and body wall, within the muscles of the body and throughout the body cavity ; these spargana were most abundant in the middle third of the entire body length (Plate II, figs. 1-3). From one Fresh-water Snake, over 300 spargana, ranging in length from 5-213 mm., were collected.

In *Pseudechis porphyriacus*, spargana with lengths between 5-40 mm· were recovered from the peritoneum of the body cavity.

In *Hyla caerulea*, spargana were most commonly found between the muscles of the inside of the thigh regions of either hind leg. They were also recovered from between the muscles of the shoulder region.

EXPERIMENTAL.

(1) SPARGANA FROM NATRIX MAIRII.

On May 25th, 1950, spargana from the fresh-water snake (*Natrix mairii*) were fed to two young cats, A and B ; each cat was given 6 spargana. One sparganum from the same host was also fed to a laboratory-bred white rat. Twenty-three days later (June 17th), diphyllobothriid eggs, with average measurements 57μ x 35μ, were recovered from the faeces of the cats (Plate III, fig. 1). The faeces were washed thoroughly in tap water, the eggs thus obtained being put into tap water in petri-dishes. One of the developing larvae within an egg measured 32μ x 28μ, and each of the six hooks present were of equal length, 11μ. On July 29th, some of the eggs had hatched, and free swimming coracidia were observed. On the same day, locally obtained copepods, *Cyclops varicans* Sars, were placed in the petri-dish. On September 13th, the copepods were observed to be infected with procercoid larval forms. (Plate III, fig. 2). The males, as is usual, were observed to be infected, often heavily, with *Diphyllobothrium* procercoids, while the females were not infected. Some infected copepods were found dead on September 19th, and on examination they proved to be very heavily parasitized with procercoids ; one examined contained 7 procercoids, 6 of them situated in the tail region.

On September 19th, two tadpoles of *Hyla latopalmata* (Günther) were introduced into a petri-dish of fresh water containing several infected copepods. On November 11th the tadpoles were infected with plerocercoids which were conspicuous, whitish structures lying just under the skin of the host. They were found in various parts of the body and tail on the dorsal and lateral surfaces of the host (Plate III, figs. 3, 4). The growth of these tadpoles was obviously inhibited. In one, the distortion was very evident, especially in the region where the tail joins the body (Plate III, fig. 4).

These spargana were fed, on November 27th, 1950, to various animals :—

(*a*) To a small frog, *Hyla latopalmata* (Günther) bred in the laboratory from a tadpole collected at Camp Mountain, near Brisbane. It was fed one sparganum dissected from the infected tadpole. On May 7th, 1951, a sparganum of increased size was recovered from between the muscles on the inside of the thigh of a hind limb. The frog was killed by chloroform. The sparganum had also been killed and had macerated very quickly.

(*b*) One sparganum was fed to a laboratory-bred mouse (*Mus musculus albus*). On March 15th a sparganum of increased size was recovered from between the muscles of the back, in the region behind the right fore-limb. This was fed to an experimental cat. Soon afterwards this animal broke its back and had to be destroyed. No tapeworm was recovered.

(*c*) To experimental Cats (*Felis domestica*) :—

(i) One cat was fed 1 sparganum dissected from the tadpole. Sixteen days later, on December 13th, a young specimen of *Diphyllobothrium erinacei* was recovered.

(ii) One cat was fed a dead tadpole containing live spargana. On December 24th, *Diphyllobothrium* eggs (average size 56μ x 33μ) were moderately abundant in the faeces of the cat.

The white rat which was also fed a sparganum from *Natrix mairii* on 25th May, 1950, was killed and examined on December 14th, and a sparganum 120 mm. long was recovered from between the muscles of the left thigh. This sparganum had increased considerably in length, having been only 20-30 mm. long when taken from the fresh-water snake and fed to the rat. It was then fed on December 14th to a cat, and on January 11th, 1951, *Diphyllobothrium* eggs (average size 63μ x 30μ) were seen in the cat's faeces. On May 21st, one adult *Diphyllobothrium erinacei* was recovered from the intestine of the cat.

(2) SPARGANA FROM PSEUDECHIS PORPHYRIACUS.

Two host specimens were examined and in both, spargana were very abundant. Spargana from one host were placed in a corked tube and kept in a refrigerator until the following day. They were then removed and shortly afterwards placed in 0·85% saline and were observed to be alive and very active. Three of these spargana were fed to an experimental cat on October 15th, 1951 ; twelve days later (October 27th) the cat died and no diphyllobothriids were recovered.

(3) SPARGANA FROM HYLA CAERULEA.

One of the most common frogs in the greater Brisbane area is *Hyla caerulea* White, approximately one quarter of the population of which appears to be infected with spargana. Two spargana recovered from locally obtained *Hyla caerulea* were fed to an experimental cat on December 5th, 1950. A few diphyllobothriid eggs (average size 60μ x 30μ) were observed in the faeces on January 6th, 1951 ; on January 18th eggs, of average size 62μ x 31μ, were abundant. The minimum time between the feeding of spargana and the appearance of diphyllobothriid eggs in the faeces of the host was 23 days.

LONGEVITY OF DIPHYLLOBOTHRIUM ERINACEI.

Of the 2 cats, A and B, fed with spargana from *Natrix mairii* on May 25th, 1950 :—

(*a*) From cat A, 4 adult *Diphyllobothrium erinacei* were recovered from the small intestine on November 3rd, 1950. They were all about 30 cm. in length with a maximum width of 0·5 cm. The scolices were buried fairly deeply in the intestinal mucosa.

(*b*) In the faeces of cat B, *Diphyllobothrium* eggs (average size, 62μ x 31μ) were still abundant on November 22nd, 1951. (In the same faeces some eggs measured 52μ x 31μ). On November 28th, only a few *Diphyllobothrium* eggs were present in the cat's faeces and no eggs were recovered on December 12th.

VARIANCE IN EGG SIZE OF DIPHYLLOBOTHRIUM ERINACEI.

Neveu-Lemaire (1936, p. 398) states that the size of the eggs of *Diphyllobothrium erinacei* is very variable, measuring 52μ to 76μ long, by 31μ to 44μ wide.

Eggs recovered from the several specimens of *Diphyllobothrium erinacei* during the present work, varied considerably in size, the most usual egg size being 62μ long, by 31μ wide.

DISCUSSION.

Bearup (1948) showed experimentally that spargana from *Acanthopi antarctica* (Death Adder) were those of *Diphyllobothrium erinacei.* Since spargana from *Natrix mairii* and *Hyla caerulea* have now also been shown experimentally to be of *Diphyllobothrium erinacei* it seems that this tapeworm is established, at least in eastern Australia, and that a wide range of animals may serve as "reservoir" hosts for the sparganum stage in its life history. According to Galliard and Ngu (1946) and Gan (1949) the tadpole is an important host in which the plerocercoid stage develops from the procercoid. Under natural conditions they must serve as effective transmitters of spargana to other intermediate hosts, such as frogs, lizards, snakes etc.

The first larval stage, the procercoid, was bred successfully by Bearup (1948) in several species of fresh-water copepods from N. S. Wales, viz. *Mesocyclops obsoletus* (Koch), *Cyclops australis* (King) and *Leptocyclops* sp., probably *Leptocyclops agilis* (Koch). Galliard and Ngu (1946) note that previous workers had infected successfully a number of different species of *Cyclops* in other parts of the world; they themselves infected 2 species, viz. *Cyclops leuckarti* Claus syn. *Mesocyclops obsoletus* (Koch), and another unidentified species. It has been shown experimentally that *Cyclops varicans* Sars from Queensland also serves as a host for the procercoid larval stage of *Diphyllobothrium erinacei.*

Bearup (1948) recorded the appearance of eggs of *Diphyllobothrium erinacei* in the faeces of the kitten 45 days after the spargana had been fed to it. In the present experiments eggs were recovered in abundance as early as 23 days after spargana had been fed to a cat. This indicates that the worms reach their adult stage in the final host in a period of just over three weeks.

SUMMARY.

(i) A new host record is made for the sparganum of *Diphyllobothrium erinacei* (Rudolphi), viz. *Natrix mairii* Gray (Brisbane, Queensl.).

(ii) Spargana from *Natrix mairii* and *Hyla caerulea* from the Brisbane area were shown experimentally to be of *Diphyllobothrium erinacei.*

(iii) The copepod, *Cyclops varicans* Sars, was shown to act as a host for the procercoid stage in the life history of *Diphyllobothrium erinacei.*

(iv) Both poikilothermic and homoiothermic hosts, viz. tadpoles and adults of *Hyla latopalmata* (Günther) and laboratory-bred mice and rats, were shown experimentally to serve as reservoir hosts for spargana of *Diphyllobothrium erinacei.*

(v) It is postulated that the spargana recorded from Queensland hosts, as in the list already given, are all of *Diphyllobothrium erinacei.*

(vi) The adult of *Diphyllobothrium erinacei* has been shown experimentally to live almost nineteen months within the intestine of a cat (*Felis domestica*).

ADDENDUM.

In April, 1952, spargana were recovered from the muscles under the right arm of a Tasmanian Tiger Cat, *Dasyurops maculatus.* This host, from near Launceston, Tasmania, had been flown to Brisbane on dry ice. The spargana were fed to a cat, and the adult tapeworm, *Diphyllobothrium erinacei,* was recovered.

The body of the Tiger Cat was made available for examination through the kindness of Mr. G. Mack, Director of the Queensland Museum.

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EXPLANATION OF PLATES.

Plate II.

Spargana of *Diphyllobothrium erinacei* (Rudolphi) in situ in the host *Natrix mairii* (Water Snake).

Fig. 1. Spargana between the skin and muscles of the body wall, X5·6. Fig. 2. Spargana in the body cavity between the body walls and gut, X5·6. Fig. 3. Body of a Water Snake pinned out to show a very heavy infection of spargana, X2·8.

Plate III.

Stages in the Life History of *Diphyllobothrium erinacei* (Rudolphi).

Fig. 1. Eggs in faeces of an infected cat, X90. Fig. 2. *Cyclops varicans* Sars with procercoid larval forms in the thorax and abdomen, X90. Figs. 3 and 4. Tadpoles of *Hyla latopalmata* (Günther) with plerocercoid larval forms (spargana) distorting both the body and tail regions of the host, X5.


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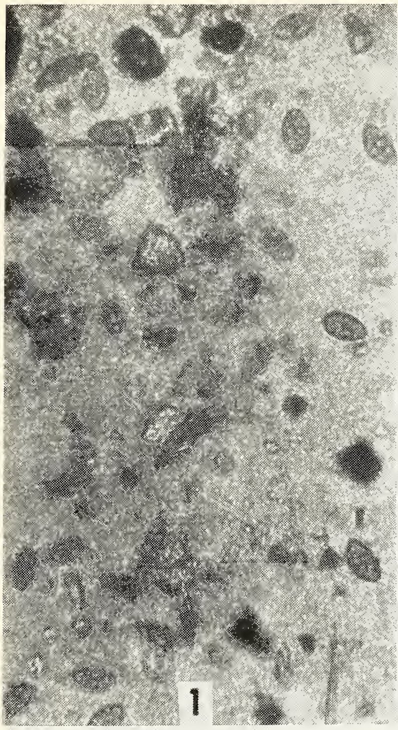
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Vol. LXIII., No. 6.

TWO NEW METASTRONGYLE LUNG-WORMS FROM AUSTRALIAN MARSUPIALS.

By M. Josephine Mackerras and Dorothea F. Sandars*, Queensland Institute of Medical Research, Brisbane.

(With 6 Text-figures and Plates IV—VI.)

(*Received 20th December,* 1951; *issued separately 6th July,* 1953.)

During the last two years forty-five specimens of the common, short-nosed bandicoot, *Isoodon obesulus* Shaw and Nodder, have been examined for parasites. The bandicoots were collected in various Brisbane suburbs and at Mount Nebo, Mount Tamborine, Nambour, and Gympie. Lung-worms were found in three specimens, all of which came from Indooroopilly, a suburb of Brisbane.

Two marsupial mice, *Antechinus flavipes* Waterhouse, were examined during the same period. One, which was collected at Mount Glorious, had a heavy infestation of lung-worms.

As far as can be determined, there are no previous records of lung-worms in marsupials in Australia, although Travassos (1925) and (1946) described two lung-worms from South American opossums. The parasites recovered from the bandicoots and the marsupial mouse are sufficiently different from each other and from previously described species to warrant the erection of two new genera, for which the names *Marsupostrongylus* and *Plectostrongylus* are proposed.

The worms were fixed in hot 70% alcohol and preserved in 70% alcohol with 5% glycerine. Unless otherwise stated, examinations and measurements were made in lacto-phenol.

MARSUPOSTRONGYLUS n. gen.

GENERIC DIAGNOSIS: Metastrongylidae with delicate cuticle, which may be thrown into minute irregular ridges; no buccal cavity, oesophagus very short, clavate; intestine wide. Male with very small bursa, rays much reduced in size, anterior ray bilobed, lateral trilobed, externo-dorsal single, dorso-dorsal ray absent or represented by papillae. Spicules equal and similar, ending distally in membranous expansions; gubernaculum absent. Female with vulva immediately in front of anus, vagina short, with moderately developed muscular wall. Ovoviviparous. Parasites of the lungs of marsupials.

TYPE SPECIES: *Marsupostrongylus bronchialus* n. sp.

Marsupostrongylus is perhaps most nearly related to *Heterostrongylus* Travassos, from the lungs of South American opossums. It differs from it in having the spicules equal, in lacking a gubernaculum and in the absence of a dorso-dorsal ray. The bursa of *Heterostrongylus* is quite large, with well-developed dorsal rays, whereas in *Marsupostrongylus* it is small, with externo-dorsal rays short and the dorso-dorsal ray rudimentary.

It differs from *Plectostrongylus* n. gen. in general body form, in the strongly ornamented cuticle, in the blunt posterior end of the female, in the short vagina without a strongly developed ovijector, and in the absence of a gubernaculum in the male.

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* And Department of Social and Tropical Medicine, University of Queensland.

MARSUPOSTRONGYLUS BRONCHIALUS n. sp.

HOST: *Isoodon obesulus* Shaw and Nodder, from Indooroopilly near Brisbane, South Queensland.

Holotype male and allotype female in the collections of the Queensland Museum.

HABITAT: The worms were orientated in the same way in all three infected bandicoots. They lay parallel to each other in the primary bronchus of each lung, with their posterior ends free in the lumen and their anterior ends penetrating the lung. As the primary bronchus was opened up, it was seen that some worms had entered each secondary bronchus, and as these in turn were opened up it was found that finally each female had penetrated singly into a bronchiole. The sharply tapered anterior end of each worm was pushed into a very fine bronchiole so that its head came to lie near the pleural surface of the lung.

The intestine of each worm was filled with brownish-black altered blood. Seen through the transparent cuticle, these dark tubes contrasted strongly with the milky-white uterine tubes (Plate IV). The males were usually lying free in the bronchi alongside the females, and their intestines were also filled with altered blood.

MALE: Length, 9 to 12 mm.; maximum width, 0·32 mm. at about 2 or 3 mm. from the anterior end. The body tapers towards each end, the width at the mouth is 0·036 mm., at the oesophageal-intestinal junction, 0·1 mm. and at the cloaca, 0·06 mm. The posterior end is slightly curved ventrally. The cortical layer of the cuticle is extremely delicate and voluminous. It has a tessellated appearance due to a mosaic of minute, irregular ridges. Some of these ridges have a definite transverse trend, giving the appearance of cross-striations in optical section. This layer is very loosely attached and is readily distorted during fixation and clearing. Labial and cephalic structures are inconspicuous; there appear to be 3 minute lips and 6 small papillae. The mouth leads into the oesophagus, which is slightly club-shaped and measures 0·23 mm. in length by 0·05 mm. in maximum breadth (cf. ♀ Plate V, figs. 1 and 2). The testis is coiled near the anterior end, and the male duct passes back parallel to the intestine.

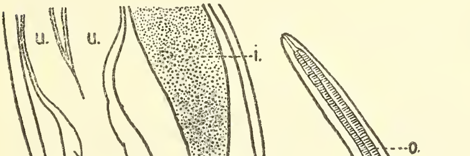
The bursa is small and delicate, with very short, stumpy rays (Plate V, fig. 5); the ventro-ventral and latero-ventral arise from a common trunk; the base of the lateral lobe is broad and relatively thick; the antero-lateral and postero-lateral rays appear as papilliform projections on either side of the medio-lateral ray; the externo-dorsal is single and rather slender; the dorso-dorsal ray is apparently represented by two papillae, one on either side near the base of the externo-dorsal ray; between these papillae there appears to be a row of four ill-defined papillae (Text-fig. 2).

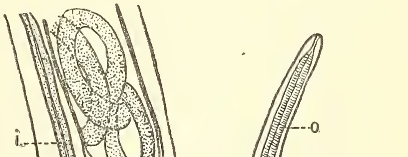
The spicules are similar in size and shape measuring about 0·11 mm. by 0·01 mm. in maximum breadth. They are brown, narrow and curved. Proximally each ends in an irregular knob, while distally it expands into a membranous tip supported by three very delicate struts (Plate V, figs. 3 and 6). Neither gubernaculum nor telamon was detected.

FEMALE: Length, 20 to 35 mm.; maximum width, 0·8 to 1·0 mm. The body is fusiform, tapering very markedly anteriorly so that the anterior end somewhat resembles a well-sharpened lead pencil. The diameter at the mouth is 0·05 mm., at the oesophageal-intestinal junction, 0·19 mm. The width then increases very rapidly to 0·8 or 1·0 mm. at the region of the first uterine coils, which lie about 4 mm. from the anterior end. There is a distinct bulge at this point. The body then gradually narrows posteriorly, being about 0·5 mm. wide for the greater part of its length. It decreases to 0·27 mm. at the level of the junction of the uteri, and to 0·11 mm. at the vulva. The vulva is situated immediately in front of the anus which is 0·06 mm. from the rounded posterior end (Plate V, fig. 4; text-fig. 1).

The cuticle, mouth and oesophagus are similar to those of the male; the oesophagus measures 0·23 to 0·27 mm. by 0·05 to 0·06 mm. in maximum section. The nerve ring appears to be a little anterior to the mid-point of the oesophagus. The ovaries begin anteriorly and are thrown into several coils. The uteri, which are packed with developing ova, pass posteriorly parallel to the intestine. The uteri unite at about 0·3 mm. from the vulva. The vagina is relatively short, with moderately muscular walls. Ovoviviparous.

FIRST STAGE LARVA in uterus of female: Length, 0·23 mm. by 0·015 mm. in maximum diameter. There is a slender buccal cavity which leads into the oesophagus. This is 0·105 to 0·115 mm. long; it widens slightly posteriorly where it is about 0·006 mm. in diameter. The intestine and anus are well differentiated. The nerve ring lies 0·06 mm. from the anterior end, the tail ends in a sharply pointed, spur-like knob (Text-fig. 3).





Text-figs. 1-3. *Marsupostrongylus bronchialus* n. sp. 1. Posterior end of female 2. Male bursa; 3. First-stage larva.

Text-figs. 4-6. *Plectostrongylus fragilis* n. sp. 4. Posterior end of female; 5. Male bursa; 6. First-stage larva. a. anus; a.l. antero-lateral ray; d. dorsal papilla; e.d. externo-dorsal ray; i. intestine; l.v. latero-ventral ray; m.l. medio-lateral ray; o. oesophagus; p.l. postero-lateral ray; u. uterus; v. vagina; vu. vulva; v.v. ventro-ventral ray.

PLECTOSTRONGYLUS n. gen.

GENERIC DIAGNOSIS: Metastrongylidae with smooth cuticle; body filiform; no buccal cavity; oesophagus short, simple, and slightly wider posteriorly. Male with very small bursa, rays much reduced in size, ventral ray bilobed, lateral trilobed, externo-dorsal single, dorso-dorsal ray absent or represented by papillae. Spicules equal and similar, ending distally in membranous expansions. Gubernaculum present. Female with posterior extremity straight, tail pointed; ovijector well developed; vulva anterior to anus and close to it. Ovoviviparous. Parasites of the lungs of marsupials.

TYPE SPECIES: *Plectostrongylus fragilis* n. sp.

Plectostrongylus resembles *Marsupostrongylus* in the bursal formula and having the spicules equal. It differs from it in the possession of a gubernaculum in the male; in the female the tail is pointed, and there is a long vagina ending in a muscular ovijector, whereas in *Marsupostrongylus* the tail is blunt and the vagina is relatively very short, with moderately muscular walls.

It differs from *Heterostrongylus* in having a greatly reduced bursa, in the absence of the dorso-dorsal ray, and in having the spicules equal and similar.

In the extreme reduction of the dorsal ray it seems to resemble *Pneumostrongylus* Mönnig from the impala, but differs from it in the reduced bursa, the bursal formula, the presence of a gubernaculum, the absence of a telamon. The eggs of *Pneumostrongylus* are segmenting when laid, whereas *Plectostrongylus* is ovoviviparous.

PLECTOSTRONGYLUS FRAGILIS n. sp.

HOST: *Antechinus flavipes* Waterhouse, from Mount Glorious, South Queensland.

Holotype male and fragments of females from the same host in the collection of the Queensland Museum.

HABITAT: The worms lay in the bronchioles, including the finer ones (Plate VI, fig. 7), and some even invaded the alveoli (Plate VI, fig. 6). The generic name indicates the intimate manner in which the worm is woven into the tissue of the lung.

MALE. One intact specimen, one complete but broken specimen and several fragments were obtained. The body is filiform, length 10 to 15 mm. by 0·088 mm. to 0·114 mm. in maximum diameter. The width at the oesophageal-intestinal junction is about 0·042 mm. Labia and cephalic papillae are inconspicuous. The cuticle is smooth. The mouth leads into the oesophagus, which is short, simple and slightly club-shaped, measuring 0·244 mm. in length by 0·02 mm. in maximum width. The intestine is a narrow tube.

The bursa is very small, and the rays are short and stumpy with a tendency to appear pedunculated (Plate VI, fig. 4). The ventro-ventral and latero-ventral arise from a common trunk, the ventro-ventral being the larger; these rays are incurved in all our specimens, but are shown diagrammatically as pointing outward in text-fig. 5. The antero-lateral and postero-lateral are broad and slightly larger than the medio-lateral; all the laterals arise from a common trunk; the externo-dorsal is short and blunt; the dorso-dorsal ray appears to be represented by two small papillae, one on each side near the base of the externo-dorsal ray.

The spicules are equal and similar. The proximal portion of each is broad, and the distal portion is drawn out into two fine rods, each surrounded by a membranous expansion. The spicules measure 0·09 to 0·1 mm. in length by 0·01 mm. in maximum breadth; the membranous part is about 0·04 mm. long (Plate IV, figs. 2, 3 and 5). A V-shaped gubernaculum is present (Plate IV, fig. 2).

FEMALE. No intact specimens were recovered, so the length could not be determined. However, the fragments which were obtained suggested that the females are considerably longer than the males. The maximum width of some of the fragments is 0·1 mm. The width at the vulva is 0·04 mm. and the anus 0·026 mm. The posterior end is obliquely truncated, and the tail sharply pointed. The anus lies 0·036 to 0·05 mm., and the vulva 0·09 to 0·1 mm. from the tip of the tail (Text-fig. 4).

In one specimen, fixed in formol-acetic-alcohol and stained with haematoxylin, the vagina measures 0·83 mm. in length and terminates in a muscular ovijector. The uteri and vagina are packed with ova containing well-developed embryos. The ova measure 0·05 to 0·055 mm. by 0·026 to 0·03 mm.

FIRST-STAGE LARVA in uterus of female: Length 0·19 to 0·20 mm. by 0·008 to 0·01 mm. in width. There is a slender buccal cavity leading into the oesophagus, which is 0·09 to 0·095 mm. in length. The nerve ring is situated 0·05 mm. from the anterior end. The tail is sharply pointed (Text-fig. 6; Plate VI, fig. 1).

DISCUSSION.

The metastrongylid lung-worms have been studied recently by Dougherty, who has proposed a classification and discussed the evolution of the group (Dougherty, 1949, 1951). He has divided the family into six sub-families:—Metastrongylinae, Filaroidinae, Skrjabingylinae, Pseudaliinae, Protostrongylinae and Dictyocaulinae. The Filaroidinae (with six genera) have developed mainly in the Carnivora, the Pseudaliinae (four genera) in the Cetacea and the Protostrongylinae (ten genera) in the Artiodactyla. The Dictyocaulinae contains only one genus, *Dictyocaulus*, parasitic in the Ungulata, and bearing some striking resemblances to the Trichostrongylidae. The Skrjabingylinae (5 genera) occur in the Carnivora, Insectivora and one species, *Troglostrongylus delicatus* Travassos 1946, in the South American opossum. Dougherty places *Heterostrongylus*, the only other genus known from marsupials, in the sub-family METASTRONGYLINAE, together with *Metastrongylus* which is parasitic in pigs. *Heterostrongylus heterostrongylus* Travassos 1925 was described from the lungs of the South American opossum *Didelphis marsupialis aurita* Wied. It possesses a fairly large bursa with well-developed rays, although the arrangement of the dorsal system is unusual.

The two new genera described here cannot be definitely allotted to any of the above sub-families, although they appear to resemble some of the filaroidine genera in the reduction of the bursa. We think that, until more material is studied from Australian marsupials and some of the life-histories are elucidated, it is wisest to refrain from putting these genera into any of the known sub-families.

The hosts of our new species are polyprotodont marsupials belonging to different families. *Isoodon* belongs to the Peramelidae, which includes the bandicoots and rabbit-bandicoots, ground-dwelling, insectivorous or omnivorous creatures. *Antechinus* belongs to the Dasyuridae, which includes the carnivorous marsupials, the smaller members being mainly insectivorous. The South American opossums are also polyprotodonts, belonging to the family Didelphidae, arboreal creatures, mainly insectivorous or carnivorous.

It may be that the relationships of the parasites in the Metastrongylidae are a reflection of the *habits* of the hosts rather than of their phylogeny.

ACKNOWLEDGEMENTS.

We are indebted to Dr. E. Singer of this Institute for bringing us numerous bandicoots, including two of the infected specimens, and to Mr. G. Naylor for the other infected specimen. We also would like to thank Mr. G. Mack of the Queensland Museum for identifying the marsupial hosts.

SUMMARY.

Two new metastrongylid lung-worms are described, *Marsupostrongylus bronchialus* n. gen., n. sp., from the bandicoot, *Isoodon obesulus*, and *Plectostrongylus fragilis* n. gen., n. sp., from a marsupial mouse, *Antechinus flavipes*.

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EXPLANATION OF PLATES.

Plate IV.

Marsupostrongylus bronchialus n. gen. and sp.

Bronchus of lung of *Isoodon obesulus*, opened to show the tails of lung-worms lying free in the lumen with their anterior ends entering the bronchioles. Note white uterine tubes and dark gut content of the worm.

Plate V.

Marsupostrongylus bronchialus n. gen. and sp.

Fig. 1. Anterior end of body of ♀. Fig 2. Cephalic region of same ♀ showing oesophagus and tessellated cortical layer of the cuticle. Fig. 3. Side view of tail of ♂. Fig. 4. Side view of tail of ♀. Note blood in the gut. Fig. 5. Side view of tail of ♂ showing the small bursa and rays. Fig. 6. Side view of tail of ♂ showing the tip of one spicule, which is extruded.

Scale. In fig. 1, one division of the scale is 0·05 mm. In figs. 2-6 inclusive each division of the scale is 0·01 mm. Figs. 2 and 4 are to the same scale.

Plate VI.

Plectostrongylus fragilis n. gen. and sp.

Fig. 1. First stage larva in smear made from fragments of an adult female. Fig. 2. Ventral view of tail of ♂, showing the gubernaculum, bursa, extended membranous tips of spicules. Fig. 3. Lateral view of tail of ♂, showing the spicules separated. Fig. 4. Lateral view of tail of ♂, showing bursal rays. Fig. 5. Lateral view of tail of ♂, showing spicules. Fig. 6. Section of lung of *Antechinus flavipes* showing cross sections of both ♂ and ♀ adult *Plectostrongylus fragilis* in the alveoli. Fig. 7. Section of lung of *Antechinus flavipes* showing cross sections of both ♂ and ♀ adult *Plectostrongylus fragilis* coiled up in a bronchiole.

The divisions of the scale represent 0·01 mm. in each figure. Figs. 2-5 are to the same scale; figs. 6-7 are to the same scale.

Plate V.

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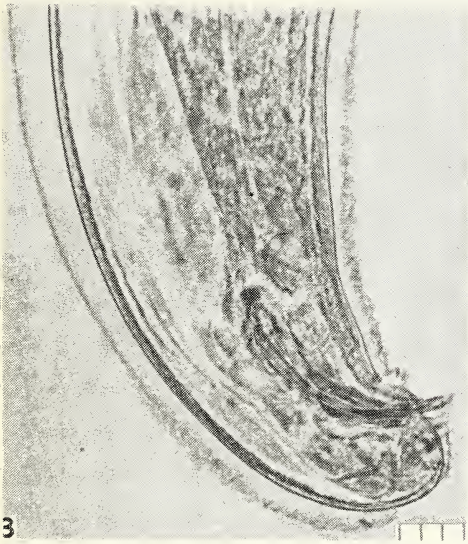

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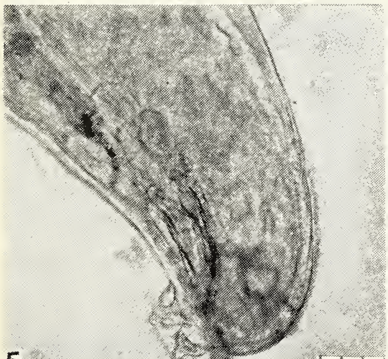

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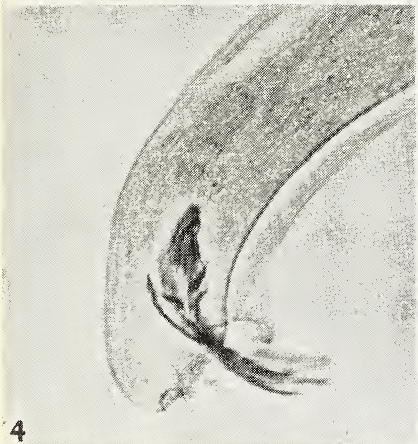

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The Royal Society of Queensland.

Report of the Council for 1950.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting the Annual Report of the Society for the year 1950.

At Ordinary Meetings throughout the year five addresses were given, while one evening was devoted to films, another to a short film followed by exhibits, and a third to three short talks.

Several original papers were accepted for publication in the Proceedings.

The Council has decided to publish a C. T. White Memorial Supplement to the 1950 Volume of Proceedings. This is at present being prepared.

The delay in publication has partly been overcome. Volume LXI. for 1949 is about to be issued, and Volume LXII. is in the press.

Our thanks are due to the Librarian for the excellent work he has done in the Library. One-third has now been catalogued, and in many cases, missing numbers in series have been obtained.

The Society has supported the establishment of a Marine Biological Research Station on the Barrier Reef.

There are now 5 honorary life members, 10 life members, 3 corresponding members, 238 ordinary members and 12 associate members in the Society. During the year the Society lost 2 members by death and 7 by resignation; 17 ordinary members and 13 associate members have been elected. Mr. L. C. Ball was elected to honorary life membership.

Attendance at Council Meetings was as follows:—M. F. Hickey, 10; D. Hill, 8; H. J. G. Hines, 7; M. I. R. Scott, 10; D. F. Sanders, 9; F. S. Colliver, 9; S. T. Blake, 9; G. Mack, 9; I. M. Mackerras, 8; A. L. Reimann, 8; J. H. Simmonds, 7; L. J. H. Teakle, 7; H. C. Webster, 8.

M. F. HICKEY, President.

Margaret I. R. Scott, Hon. Secretary.

21st March, 1951.

THE ROYAL SOCIETY OF QUEENSLAND.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1950.

Receipts.	£	*s.*	*d.*	£	*s.*	*d.*
Balance in Commonwealth Bank, 31/12/49	454	1	7	463	13	5½
Cash in Hand, 31/12/49	9	11	10½			
Subscriptions:—						
1950 Ordinary Membership	209	2	0			
1950 Associate Membership	5	12	6			
Life Membership	15	15	0			
Arrears	44	17	0			
Paid in advance	1	5	0			
				276	11	6
Commonwealth Loan Interest	5	3	3			
Commonwealth Savings Bank Interest ..	8	3	1			
				13	6	4
Donation	0	5	0			
				0	5	0
Sale of Reprints	25	14	3			
Sale of Society Proceedings	47	8	10			
				73	3	1
Exchange					17	10
				£827	17	2½

Expenditure.	£	*s.*	*d.*	£	*s.*	*d.*
Government Printer—						
Cost of Vol. LX.	371	12	2			
Less Government Subsidy	175	0	0			
				196	12	2
Library Insurance					19	3
Roneoing				6	15	0
Lanternist				4	0	0
Stationery, Stamps, &c.—						
Secretary	21	1	4½			
Treasurer		11	3			
Librarian	15	15	3			
				37	7	10½
Refreshments and Utensils	8	18	11½			
Less Collections	5	9	6			
				3	9	5½
Shelving for Library				12	9	5
Subscription Notice Forms				4	3	4
Index to Vols. 1-25 Aust. J. of Exp. Biol. & Med. Science					12	6
Balance in Commonwealth Bank, 31/12/50	..			557	3	2
Cash in Hand, 31/12/50—						
Secretary		6	1½			
Treasurer		5	11			
Librarian	3	13	0	4	5	0½
				£827	17	2½

In addition to the Credit Balance shown in the above Statement, the Society holds the following Capital Funds:—

Commonwealth Loan	£200
Savings Certificates	2
	£202

Held in safe custody by the Commonwealth Bank of Australia, Adelaide street, Brisbane.

Examined and found correct.

L. P. HERDSMAN, Hon. Auditor.

DOROTHEA F. SANDARS, Hon. Treasurer.

9th March, 1951.

ABSTRACT OF PROCEEDINGS, 2ND APRIL, 1951.

The Annual General Meeting of the Society was held in the Physics Department of the University on Monday, 2nd April, with the President (Associate Professor M. F. Hickey) in the chair. About fifty members and friends were present. The minutes of the last Annual Meeting were read and confirmed. The Annual Report was adopted and the Balance-Sheet received. The Librarian reported 584 volumes and parts had been added to the library and that new exchanges had been established with the Japanese Academy of Science, the University of Southern California, and the Rancho Santa Anna Botanical Gardens.

Professor T. K. Ewer and Professor F. T. M. White were elected to Ordinary Membership.

The following officers were elected for 1951:—

President: H. J. G. Hines.
Vice-President: I. M. Mackerras.
Hon. Secretary: Miss M. I. R. Scott.
Hon. Treasurer: Miss D. F. Sandars.
Librarian: F. S. Colliver.
Editors: S. T. Blake, George Mack.
Councillors: M. J. Mackerras, A. L. Reimann, J. H. Simmonds, W. Stephenson, L. J. H. Teakle.
Hon. Auditor: L. P. Herdsman.

Before delivering his address, the President remarked as follows:—

Since the last Annual General Meeting, we have suffered the great loss of two distinguished members, Mr. C. T. White and Mr. J. B. Henderson. It is with deep regret that I recall them to your memories to-night.

Mr. White, Government Botanist at the time of his death, died in harness. For a long time a member of our Society and of the Council of the Society, he was as well-loved personally as he was distinguished scientifically. His reputation was international.

Mr. Henderson, formerly Chief Government Analyst and an outstanding member of the Public Service of Queensland, was a very old member of our Society and one held in the highest esteem. He was a trustee of the Society.

Before turning to the main part of my address I wish to express my thanks to the members of the Council for the pleasant term of office I have enjoyed. I think that the Council would wish me to express appreciation of the work done by the Honorary Librarian, Mr. Colliver, in the reorganization of the Library, the most precious material asset of the Royal Society of Queensland.

The Presidential Address, entitled "Form or Function," was delivered by Associate Professor M. F. Hickey.

ABSTRACT OF PROCEEDINGS, 7TH MAY, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 7th May, with the President (Associate Professor H. J. G. Hines) in the chair. About sixty members and friends were present. The minutes of the previous meeting were confirmed. The following were nominated for membership:—Mr. A. A. Gibson, Mr. R. N. Spratt, Mr. A. W. Draydon, Dr. F. G. Christensen and Dr. W. Hayhow for Ordinary Membership, and Miss M. Lewis for Associate Membership. Mr. F. Gipps was elected to Honorary Life Membership.

Dr. I. M. Mackerras gave a brief account of an outbreak of encephalitis in the Murray Valley, Victoria. This had been found by workers at the Hall Institute to be closely related to the Japanese B type of encephalitis. A much milder outbreak had occurred among natives at Mornington Island during February and March. Preliminary serological studies at the Hall Institute had shown that this was closely related to the Murray Valley infection. A full serological investigation was being made at Mornington Island in association with a search for the insect vectors and animal reservoirs of the infection.

Professor H. J. Wilkinson gave an address entitled ''Prehistoric Settlement of the Pacific Islands.'' He said that the Pacific Islanders are of at least three distinct types, the Melanesians, Polynesians and Micronesians, and each type is the result of the mixture of two or more of the basic racial groups. Melanesians are mostly negroid, but several other racial elements are present and vary in intensity in different parts of the Melanesian islands. Polynesians are patently a hybrid race compounded of white, mongoloid and a modicum of negroid. The Micronesians are rapidly disappearing and are not very well known, but they seem to have been allied to the Polynesians in race and culture, though with strong Indonesian mongoloid influences. It was shown how Physical Anthropology, blood grouping investigations, Ethnology, the study of languages, customs and traditions, etc., as well as of the distribution of plants and animals, are all contributing towards the solution of the problem of the origin of the Pacific Islanders and the diffusion of culture in the Pacific. Comments were made on the recent book by Gladwyn ''Men out of Asia'' and on the significance of Hayerdahl's ''Kon Tiki Expedition.'' The lecture was profusely illustrated with lantern slides.

Abstract of Proceedings, 25th June, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 25th June, with the President (Associate Professor H. J. G. Hines) in the chair. About thirty members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Membership:—Mr. A. A. Gibson, Mr. R. N. Spratt, Mr. A. W. Draydon, Dr F. G. Christensen and Dr. W. Hayhow to Ordinary Membership; and Miss M. Lewis to Associate Membership.

Dr. Owen Jones exhibited a part of the lower and upper jaws with well preserved teeth of *Ichthyosaurus australis* McCoy, from near Richmond, Central Queensland. The specimen was sent to Professor S. F. Lumb who passed it on to the Geology Department of the University.

Professor W. H. Bryan exhibited a new geological map of Brisbane on a scale of 1 mile to an inch, prepared by himself and Dr. Owen Jones. It shows much more detail of rock type and structure than earlier maps.

Professor W. H. Bryan exhibited a fine specimen from the quarry in the Brisbane Tuffs at Stafford. The specimen is of a rhyolitic agglomerate with large fragments of phyllite. It was probably derived from the throat of a nearby volcano.

Research Professor A. L. Reimann exhibited a new type of monochromatic optical filter, a Barr and Stroud ''interference filter,'' having a narrow transmission band with its maximum transmission at the wave-length of the green mercury line, viz., 5461 A°. The location and width of the transmission band were shown by projecting a spectrum on a screen and interposing the filter in the path of the light. An outline of the theory and method of construction of this filter was given, it being pointed out that it is in principle nothing more than a logical development of the Fabry and Perot etalon, which was devised as long ago as 1901.

Mr. W. B. Mather exhibited four strains of *Drosophila melanogaster,* viz., wild type, white eye, ebony body, and ebony body-dumpy wing, used in the senior genetics course of the Zoology Department. He pointed out that *Drosophila* is ideal for cytogenetical work because it is easy to breed, has a short life cycle, has a low chromosome number, and forms giant salivary gland chromosomes. The white eye mutant is used for illustrating sex linkage and criss-cross inheritance, the ebony body for the monohybrid ratio, and the ebony body-dumpy wing for the dihybrid ratio.

Mr. George Mack exhibited two specimens, a marsupial, the brown cuscus (*Phalanger orientalis*), and a eutherian mammal, the giant rat (*Uromys caudimaculatus*). Both species are confined to Cape York Peninsula. The brown cuscus was discovered in Australia only in recent years, and the need for improved knowledge of the fauna was stressed in view of the fundamental importance of the indigenous flora and fauna in relation to soil erosion. Mr. Mack referred to the tendency to treat soil erosion as a mechanical problem, whereas, he insisted, it is primarily a biological problem.

Dr. I. M. Mackerras, Dr. M. J. Mackerras and Miss D. F. Sandars exhibited parasites of the bandicoot (*Isoodon obesulus*).

Abstract of Proceedings, 30th July, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 30th July, with the President (Associate Professor H. J. G. Hines) in the chair. About thirty members and friends were present. The minutes of the previous meeting were confirmed. Miss B. J. Excell was nominated for Ordinary Membership. 395 volumes and parts have been added to the library.

A symposium was held on ''The Zoology of Copper.'' Mr. J. M. Harvey and Mr. J. E. O'Hagan were the principal speakers.

Mr. Harvey gave a brief historical account of copper deficiency in ruminants, and then showed how copper administration had been attempted. There were five methods commonly used— (i.) Through the pastures by top dressing of the soil with copper salts. (ii.) Through the drinking water. (iii.) By oral administration as drenches. (iv.) By addition of copper compounds to exposed mineral supplements. (v.) By direct incorporation in the food.

All suffered certain disadvantages arising from either cost, lack of controlled intake, inactivation, or simply from impracticability. In the work he outlined, attempts were made to establish within the animal ample reserves of copper from which the necessary small continual releases could take place. The methods used were—(*a*) Oral administration, (*b*) Intramuscular injection, (*c*) Subcutaneous injection, (*d*) Implantation, and the preparations used were organic and inorganic compounds of copper of both soluble and insoluble types. All were either readily available, or presented no great difficulty in preparation. Balance sheets were kept to assess copper retention. Though some untoward experiences—abscesses, necrotic areas and even deaths—were recorded, it was eventually possible to employ intramuscular injection of soluble copper salts of simple inorganic and organic acids, and implantation of the copper compound of Hahn's oxine reagent (8 hydroxyquinoline). These are promising and large scale field trials are envisaged.

Mr. O'Hagan said that with one exception, the copper uroporphyrin complex turacin first found in the feathers of certain African birds, copper occurs in plant and animal tissues in combination with proteins. These copper proteins can be divided into three classes (i.) the plant and animal oxidases, (ii.) the haemocyanins, (iii.) the animal copper proteins of blood, liver, etc. The oxidases, laccase, tyrosinase and ascorbic acid oxidase, are enzymes responsible for the respiratory activity of many plants. Evidence of their activity is the darkening of many cut plants (such as the sweet potato tuber and the banana) on contact with air. The haemocyanins, the respiratory pigment of the blood of crabs, lobsters, octopi, snails, certain worms and molluscs have molecular weights varying from 350,000 to 5,000,000, contain two atoms of copper per molecule and can carry up to 25 ml. of oxygen per 100 g. of protein. They resemble the haemoglobins but have copper in place of iron. The animal copper proteins, haemocuprein and hepatocuprein occur respectively in the blood and liver of higher animals and man. These proteins are responsible for the storage, transport and perhaps the activity of copper as a necessary component of the system or systems responsible for the synthesis of haemoglobin, cytochrome and cytochrome oxidase. It was shown that copper plays an essential role in the respiratory activity of plants, animals and men.

Abstract of Proceedings, 27th August, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 27th August, with the President (Associate Professor H. J. G. Hines) in the chair. About forty-five members and friends were present. The minutes of the previous meeting were confirmed. Miss B. J. Excell was elected to

Ordinary Membership. Mr. R. Millar was nominated for Ordinary Membership. The Librarian reported that sixty-six volumes and parts had been added to the Library during August, and that a new exchange had been established with the Hungarian Academy of Science.

Professor Schonell gave an address entitled "Psychology in Educational Practice." A lengthy discussion followed.

ABSTRACT OF PROCEEDINGS, 24TH SEPTEMBER, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 24th September, with the President (Associate Professor H. J. G. Hines) in the chair. About thirty-five members and friends were present. The minutes of the previous meeting were confirmed. Mr. R. Millar was elected to Ordinary Membership. The Librarian reported that 130 volumes and parts had been added to the Library since the last meeting, and that a new exchange had been established with the Finnish Academy of Science.

Mr. James J. Bollich spoke on "The Relationship of Gravity, Magnetism and Atmospheric Electricity to Tectonics." He said that as more and more data concerning the phenomena of gravity, magnetism, atmospheric electricity, earth-currents, and earthquakes are accumulated it is becoming increasingly apparent that these phenomena are very closely related. If this relationship exists it then seems reasonable to assume that these phenomena must all originate from a single cause. The speaker proposed a hypothesis based upon differential rotation between crustal and subcrustal material of the earth, comparable to the difference in the speed of rotation of the two mediums of a revolving glass of water, to explain these phenomena. This mechanism has been advanced previously to explain magnetism and atmospheric electricity and the speaker believes that it should be investigated further as the force responsible for crustal deformation.

Dr. R. Gradwell spoke on "Petrological Research at Imperial College, London." He described research being carried on at the Geology Department of the Imperial College of Science and Technology by Professor H. H. Read and his staff and students. Most of this research concerns Plutonic rocks, and it was pointed out that great importance is attached to field geology. Ironstones from Wellingborough, England, were exhibited and some colour slides of the open-cut workings were shown. Shap and Cornish granites were also exhibited.

Dr. Owen Jones informed members that at a meeting held in May and representative of the Geologists of Australia it was decided to form a Geological Society of Australia. He gave an outline of the proposed constitution and explained that the main object of the Society was to publish papers of a high standard, particularly those of world-wide interest and ones which are too long for the journals of existing societies.

Dr. Dorothy Hill exhibited R. van Bemmelen's "Geology of Indonesia," a work in two volumes with a case of maps, which sets out the results of 100 years' work, mainly by the Dutch, in Indonesia, and interprets the findings in the light of his theories on the relation between earth movement and igneous activity.

Associate Professor F. W. Whitehouse exhibited new early Carboniferous fossils from Newry Island, and a new genus of early Cretaceous lamellibranchs from near Tambo.

Mr. Grahame Tweedale exhibited some specimens of slate greenstone, phyllite and altered basic lavas from the Gogango Range, between Rockhampton and Duaringa, introducing the exhibit with a few remarks on the geological structures of the area. The Gogango High divides the Yarrol Basin, with its Devonian, Carboniferous and Permian sediments, from the Permo-Carboniferous Bowen Basin to the west. Slates of the type exhibited are very rare in Queensland, and a further interesting feature is their association with regionally metamorphosed schists, phyllites and greenstones.

Abstract of Proceedings, 29th October, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 29th October, with the President (Associate Professor H. J. G. Hines) in the chair. About twenty members and friends were present. The minutes of the previous meeting were confirmed. Mr. J. E. Kindler was nominated for Ordinary Membership. The Librarian reported 184 additions to the library, and the establishment of a new exchange for Memoirs of Das' A'lvaro de Castro Museum, since the last meeting.

Dr. M. C. Bleakly gave an address entitled "Some Features of the Development of *Callorhynchus milii* (Elephant Fish) having a bearing on the Primitiveness of the Holocephali." Three points from the development of *Callorhynchus milii* were considered. A study of the development of the jaw suspension, of the relations of the spiracle up to the time of its closure, and of the development of the hyoid skeleton supports the view that the complete hyoid skeleton, unique amongst living vertebrates, is a retained primitive feature and not a secondary modification. The kidney shows features more primitive than that of any jawed vertebrate since all the segments from which it is developed are retained, are recognisable and are functional in the adult. The relations of the mandibular arterial arches to the trabeculae of the developing skull are as in all vertebrates save the Selachii which therefore appear to be a modified group. These features support the view put forward by de Beer that the Holocephali are not derived from the Selachii but represent the more primitive living Gnathostomes known.

Abstract of Proceedings, 26th November, 1951.

The Ordinary Monthly Meeting of the Society was held in the Physics Department of the University on Monday, 26th November, with the President (Associate Professor H. J. G. Hines) in the chair. About fifty-five members and friends were present. The minutes of the previous meeting were confirmed. Mr. J. E. Kindler was elected to Ordinary Membership. The Librarian reported the addition to the library of 119 volumes and parts for November.

A Symposium on ''Aerial Photographic Interpretation'' was held.

Mr. Newell explained the general principles behind the taking of aerial photographs, the principles of stereoscopy and various aspects, optical and cartographic, in the preparation of maps for aerial photographs.

Mr. Reilly, with the aid of lantern slides, described the equipment used to-day in the Department of the Surveyor-General for the making of topographic maps from aerial photographs.

Major Herridge (D.A.D. Survey), exhibited the several types of maps prepared by the Army for aerial photographs and discussed the techniques employed.

Mr. Woods illustrated the use to which aerial photographs are put by the Queensland Forest Service for making special maps for delimiting the distribution of timbers of economic importance.

Mr. Tweedale discussed pattern mapping and the uses that are being made of it at present in preparing a new Geological Map of Queensland.

Associate Professor Whitehouse, with the aid of lantern slides of aerial photographs, demonstrated a variety of special applications—road locations, soil survey, coastal problems, etc.

A. H. TUCKER, Government Printer, Brisbane.

GUIDE FOR THE PREPARATION OF SYNOPSES

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1. PURPOSE.

It is desirable that each paper be accompanied by a synopsis preferably appearing at the beginning. This synopsis is not part of the paper; it is intended to convey briefly the content of the paper, to draw attention to all new information and to the main conclusions. It should be factual.

2. STYLE OF WRITING.

The synopsis should be written concisely and in normal rather than abbreviated English. It is preferable to use the third person. Where possible use standard rather than proprietary terms, and avoid unnecessary contracting.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The synopsis should therefore be intelligible in itself without reference to the paper, for example it should not cite sections or illustrations by their numerical references in the text.

3. CONTENT.

The title of the paper is usually read as part of the synopsis. The opening sentence should be framed accordingly and repetition of the title avoided. If the title is insufficiently comprehensive the opening should indicate the subjects covered. Usually the beginning of a synopsis should state the objective of the investigation.

It is sometimes valuable to indicate the treatment of the subject by such words as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

It should contain the names of any new compound, mineral, species, etc., and any new numerical data, such as physical constants; if this is not possible it should draw attention to them. It is important to refer to new items and observations, even though some are incidental to the main purpose of the paper; such information may otherwise be hidden though it is often very useful.

When giving experimental results the synopsis should indicate the methods used; for new methods the basic principle, range of operation and degree of accuracy should be given.

4. DETAIL OF LAYOUT.

It is impossible to recommend a standard length for a synopsis. It should, however, be concise and should not normally exceed 100 words.

If it is necessary to refer to earlier work in the summary, the reference should always be given in the same manner as in the text. Otherwise references should be left out.

When a synopsis is completed, the author is urged to revise it carefully, removing redundant words, clarifying obscurities and rectifying errors in copying from the paper. Particular attention should be paid by him to scientific and proper names, numerical data and chemical and mathematical formulae.

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