and gait change gradually, and there is no sharply defined change-over from walking rhythm to running rhythm. Records of the electrical and contractile activity in isolated preparations of the flexor muscle of the tibia have led to the conclusion that the individual muscle fibres have a multiple innervation and can contract at different speeds. There are at least three different patterns of action potential records, correlated with different speeds of contraction. It is suggested that changes in the number or type of nerves involved in stimulating the muscle fibres can produce changes in the speed of contraction of the fibres, and thus bring about the graded changes in the speed and gait of the whole insect.

Much can be learned about the performance of a muscle by finding what force it can exert in contraction, and by analysing the relationship between the force exerted and the velocity of shortening. The equation relating force to velocity is

$$(P + a)\,(V + b) = \text{constant} = (P_0 + a)b,$$

where P is force, V is velocity, a and b are constants, and P_0 is the force exerted under isometric conditions, that is, where velocity is zero. A. V. Hill has shown that this equation not only fits the force–velocity curve but also expresses the way in which heat is emitted during contraction. It is therefore important to find how far different kinds of muscles and the muscles of different animals have mechanical properties which can be expressed by this equation. B. C. Abbott and D. R. Wilkie (Departments of Biophysics and Physiology, University College, London) have studied this question. Their experiments were made on isolated muscles from snails, dogfishes, rays, tortoises, frogs and toads, and results have also been obtained for human muscles by experiments on intact subjects. In all these muscles the tension developed during isometric contraction depends on the length at which the muscle is held, being greatest at about the length the muscle has in the body. During isotonic contraction, the greater the weight that the muscle has to lift the smaller is the amount of shortening. The velocity of shortening is greatest when the weight is least, and the equation relating force to velocity is the same for all the muscles investigated. The most striking difference found was in the maximal velocity the muscle could attain : this varied over a sixty-fold range from snail to man.

In the last paper, Dr. E. Jean Hanson (Medical Research Council Biophysics Research Unit, King's College, London) dealt with two aspects of muscle cytology relevant to comparative studies of muscle physiology. The cross-striations of isolated vertebrate and insect myofibrils have been studied in positive phase-contrast illumination, in polarized light and in the electron microscope. Isolated fibrils have been induced to contract by treatment with adenosine triphosphate, and the process of contraction has been watched in the microscope and the changes in the pattern of cross-striations studied. The conclusion has been reached that a material, provisionally called the 'A substance', which is segregated in the isotropic bands of relaxed fibrils, migrates during contraction along the long axis of the fibril, and most of it comes to lie in a set of new bands, the contraction bands, at the end of contraction. In spite of this change in the distribution of materials, the alternation of anisotropic and isotropic bands along the length of the fibril remains unchanged, and the factors responsible for birefringence are unknown. Contraction of myofibrils induced by adenosine triphosphate is irreversible, but there is reason to suppose that in other respects it is similar to normal contraction and that a migration of the unknown 'A substance' takes place when a muscle contracts *in vivo*. Finally, some observations on the smooth muscles of molluscs and annelids were briefly reported ; the muscles investigated included those discussed earlier in this meeting by Lowy, Abbott and Wilkie. Fibres of these invertebrate smooth muscles, unlike the fibres of striped muscles, contain large quantities of proteins of the paramyosin type, about which little is yet known. Whereas a striped muscle fibre consists predominantly of actin and myosin, the two structural proteins concerned in contraction, molluscan and annelid smooth muscles have complex fibres consisting both of contractile myofibrils and of bundles of paramyosin or related fibrils. These bundles are responsible for the characteristic double oblique striation of these fibres. Paramyosin is very unlikely to be contractile, and it may be mainly responsible for many of the peculiar properties of these smooth muscles, for example, their extensibility and 'viscosity'.

[1] *Phil. Trans. Roy. Soc.*, B, **237**, No. 640 (1952).

CLASSIFICATION OF THE FUNGI

LIEUT.-COLONEL R. B. SEYMOUR SEWELL took the chair at the meeting of the Linnean Society on October 23, when a discussion was held on the "Classification of the Fungi".

Dr. B. Barnes said that the lower fungi, or Phycomycetes, are a heterogeneous group, separated from the other fungi by the usually cœnocytic vegetative body. This may be a rounded or lobed sac, a branched structure of characteristic shape, or, in the higher forms, a spreading mycelium. Septation in the vegetative body usually accompanies the formation of reproductive organs. In origin, septation may have been associated with the production of reproductive structures carried above the bacterial slime on the submerged substrata inhabited by many of these fungi. It seems likely that, during the course of evolution, septum formation has moved backwards in ontogeny ; in some existing species, septate vegetative bodies occur in juvenile specimens. The septate vegetative body may well be in a physiological condition intermediate between that of the vegetative state and of the reproductive state.

Phycomycetes show some peculiar features distributed rather haphazardly among the members of the group, features scarcely of adaptive significance and more probably inheritances from the remote past. Notable among these features are : the persistent empty wall of the zoospore, the occurrence of two phases of motility with differences in morphology of the zoospore (diplanetism), and the assumption of amœboid characters by the zoospore. These features occur chiefly in a number of the Chytridiales and the Saprolegniales. From these two stocks, rather vague connexions may be traced to the other alliances of the Phycomycetes.

The Monadineæ Zoosporeæ occur as parasites or as saprophytes in algæ, fungi and bryophytes, and probably as common saprophytes in the soil. They are very simple, and can scarcely be regarded as fungi, though in life-history and in organization they agree well with the simpler members of the Chytridiales and Saprolegniales. They differ in the tardy formation of a wall around the trophic body and in the ingestion of solid food with the ejection of solid residues of digestion. In the Monadineæ Zoosporeæ and in the Phycomycetes, series may be traced, characterized by uniflagellate, biflagellate and non-flagellate spores: this appears very significant. Some of the Monadineæ Zoosporeæ leave persistent empty zoospore walls, and some show signs of diplanetism; amœboid stages are common. These points also are significant. Many members of the group are very common and they deserve more study than they have yet had. If this shows that features of life-history and behaviour are common to some of the simplest organisms yet known, and to the Phycomycetes, it must follow that the fungi are not plants, but lie on lines of development separate from those which run through the animals and the green plants. It must follow that the fungi are not decolorized algæ. Such research must be directed to the tracing of tendencies, and not to an effort to show that an existing species or genus is ancestral to, or derived from, another existing species or genus.

Dr. E. J. H. Corner pointed out that the purpose of classification is the identification of organisms and the recognition of their positions in an evolutionary system. Artificial systems frustrate research. Classification is concerned with genera, tribes and families. Speculation about phylogeny is an essential part of the work, for speculation is the ignition of taxonomy.

The classification of the higher Basidiomycetes is very backward. It is too artificial to stimulate research, and too inaccurate to permit the reliable identification of the organisms. The physiology, genetics and ecology of the higher fungi must be brought into the account, for these are living topics.

The higher fungi have a mycelium and a fructification. The mycelium is too generalized to be of use in classification; it is very uniform, and doubtless very efficient. The fructification must be used. What is a mushroom? It is a precise device for the production and liberation of spores. The gills are put out of action when they are immersed in water, and the basidia collapse; therefore, drawings of basidia are usually artificial. The mushroom is an umbrella which protects the gills from rain but maintains humidity around the spores; the polypore is a bracket which acts similarly. In contrast, the discomycetous apothecium is a cup which holds water.

Clavaria has no protection for its spores, and shows the primitive arrangement. A survey of the world flora of clavarioid fungi shows that they contain at least six natural series of genera or groups of genera. The Clavariaceæ, as currently understood, is therefore an artificial assemblage. There is a set of tropical Clavariaceæ which shows a general agreement with the polypores. A great group of species, with yellow-brown fruit bodies, cuts right across the accepted lines of classification, and contains clavarioid, stereoid and hydnoid forms. In some members of this group, the hyphal walls thicken early. This hinders growth, and would prevent the development of a fructification of mushroom type, for that depends on thin-walled hyphæ.

The genera of the higher fungi need to be dissected out into phylogenetic units. For example, *Fomes applanatus*, *F. igniarius* and *F. fomentarius* look much alike; but microscopic analysis shows them to be very different. Use of the method of hyphal analysis will reveal many other examples, and may yield good evidence of relationships.

If *Clavaria* is primitive, the ends of the lines of development in the Gasteromycetes are doubtless mixed groups. It seems certain that the resupinate Thelephoraceæ are to be derived along a number of lines of development within the Hymenomycetes; even *Pterula* may have resupinate fructifications.

Dr. J. Ramsbottom said that the objects of classification are the identification of organisms and their arrangement in a scheme showing relationships; differences in physiology and in chemistry must be taken into account. Schemes of classification based on presumed affinities may be valuable aids to identification, just as are artificial keys, though these can be deceptive because they often give meagre details. In large herbaria, an artificial scheme can be justified on grounds of convenience; even an alphabetical arrangement can be defended.

Morphological characters may be of little use, as in the yeasts, where it has been necessary to use the methods developed by the bacteriologists in classification.

Fungal cultures often produce saltations, mutations and strains, and these new forms may remain constant in subsequent cultures. Parasitic fungi, such as the rusts, have biological races, which may arise by mutation or by natural hybridization. Some of the biological races of *Puccinia graminis* are very virulent. Natural or induced variation has been of great importance in the production of penicillin. After the Americans had found that *Penicillium notatum* would not grow in submerged culture, they found a good strain on a rotting melon, and improved it by treatment with X-rays and other means. These strains and biological races cannot be neglected by the taxonomist, if only because of their economic significance. Experience gained during the search for antibiotics has shown that the fungi cannot be classified on their products; mycology and biochemistry are not synonymous.

Attempts have been made to identify toadstools by the use of sulphovanillin and other chemicals; but such tests have not been used with discrimination. Nothing seems to be known of the results of applying these chemicals to the same species at different stages in development. The tests are crude, and they are not critical.

Little is known of natural variation in the fungi. *Laccaria laccata* is well known to vary greatly; but is it variable because it is common, or common because it is variable? *Armillaria mellea* is variable; but little has yet been done on its systematics. It has forms with and without rings. In the old classification, the ring was held to be of great importance, and it is still held in respect. The old classification of the agarics was based on spore colour and on gross morphology. It is quite artificial, but we must continue to use it, for there is nothing to replace it. The logical method would be to associate all species with comparable developmental histories, no matter what the spore colour or the arrangement of the gills. Spore-sculpture needs much more study, as has been pointed out by some French workers.

Most of the phylogenetic schemes proposed for the higher fungi are of no importance; they may be described as "evolution in our time". Certainly, fungi are not decadent algæ.

Much more detailed knowledge is required before good theoretical schemes can be constructed. Even before the idea of evolution was accepted, mycologists had recognized circles of affinity within the fungi. Evolution cannot be both the key to the problem and also the lock. A study of phylogeny may indicate what forms are primitive, and these are probably the simplest. But the evolutionary history of the higher fungi is still a mystery. A study of fairy rings suggests that the mycelium is much more important in reproduction than is the spore, and yet we have elaborate and extremely fertile fruit bodies.

Microscopic characters are of great significance in dealing with species, and hyphæ, as in the strands of *Merulius lacrymans*, may show much diversity of structure; they may have taxonomic significance. Biological characters must not be stressed too much. For example, the predacious fungi show a general and similar pattern of behaviour, but the predacious habit is to be found among Phycomycetes, Basidiomycetes and Hyphomycetes. B. BARNES

ASH AND CLINKER IN INDUSTRY

By T. F. HURLEY, O.B.E.
Fuel Research Station, London, S.E.10

DURING October 28–29, a conference described as "A Special Study of Clinker and Ash in Industry" was held by the Institute of Fuel at the Institution of Mechanical Engineers. Twelve papers were discussed which covered the origin and nature of the mineral matter in coal; its laboratory examination; the extent to which it is responsible for atmospheric pollution; the methods by which it can be removed either from the coal itself or from the products of combustion; and its effect upon the utilization of coal in various types of industrial plant. The papers had been published in advance in the *Journal of the Institute of Fuel*, and the Institute hopes to publish the text of the papers and discussions in the near future (£1 1*s*.).

In the field of utilization, small industrial boilers, gas producers, steel works plant, and, looking ahead, the industrial coal-fired gas turbine were considered, but most attention was devoted to the large water-tube boilers used by the British Electricity Authority, which is the largest single user of coal. This one organization now consumes 35 million tons of coal per annum, and as the average ash content of the rough slack supplied to it is about 15 per cent, it has to deal with about 5 million tons of ash per annum. Merely to handle this quantity of waste material is a formidable task, but during recent years the problems associated with ash and clinker have been further increased as a result of the present tendency to generate electricity in mammoth power stations employing very large and costly boilers working at extremely high temperatures and pressures. Among other consequences, the size of the stations requires more elaborate and expensive plant to avoid excessive atmospheric pollution in their vicinity, the higher temperatures in the boilers lead to a more objectionable type of deposit upon the heating surfaces, and to take one of a small number of very large boilers off the line for cleaning out of its turn affects materially both the output of the station and the cost of the electricity generated.

Taking industry as a whole, the importance of ash is steadily increasing as a result of changing mining conditions, which have led to more and more mineral matter being included in the coal brought to the surface. Various reasons were given at the Conference, the chief of which were, first, that the better seams have been worked out and those now being mined not only contain more ash but also include more dirt bands; and, secondly, increased mechanization causes more dirt to be mined and at the same time reduces the quantity which can be removed from the coal underground. Excluding 'free dirt', British coal seams still contain on the average only 5·5 per cent of ash and probably compare favourably in this respect with those of other major coal-producing countries; but for the reasons given, run-of-mine coal now includes on the average about 15 per cent of free dirt. This represented about 33 million tons of the 'raised and weighed' output for 1950.

It is obvious that the cost of mining dirt and bringing it to the surface is comparable with that of winning coal; but no suggestion was made at the Conference that the quantity of dirt brought to the surface could, or should, be reduced. In fact, a future increase in the ash content of coal was accepted as natural and inevitable.

Ash costs just as much as coal to convey from the pit head to the point of utilization, and at each stage beyond that it is a costly nuisance. Again taking modern power station practice as an example, ash costs more to pulverize than coal and it causes more wear in the machinery; it affects adversely the efficiency of combustion; it requires the size and therefore the capital cost of the boilers to be larger and at the same time it increases the difficulties of design and operation; it necessitates the provision of ash-handling equipment comparable in size and cost with the boilers themselves; some of it forms objectionable deposits which reduce both the efficiency and the availability of the boiler; it requires the installation of expensive dust collectors to minimize atmospheric pollution and, even when it has been collected, its disposal is a major difficulty.

Many, but not all, of these effects can be reduced materially by using known methods of cleaning the coal at the pit, but this involves a high cost in capital equipment, power and labour. So recently as 1950 the National Coal Board asked in its annual report whether "it may sometimes not be more economical to save some or all the cost of coal preparation at the price of reduced efficiency in the final stage of conversion". To this question the National Coal Board itself now appears to provide its own answer by stating that when all the cleaning plants ordered between vesting date and the end of 1951 are in operation, they will deal with about 42½ million tons of coal per annum. More than 100 million tons of coal are already cleaned mechanically each year.

On the other hand, the Conference showed that there is considerable divergence of opinion with regard to the extent to which it is economical to wash coal instead of dealing with the ash during utilization. This lack of agreement may arise from the wide variations which occur in the chemical composition of the mineral matter in coal and in the manner in which it is associated with the coal substance. Both the ease with which coal can be cleaned and the influence exerted by a given quantity of ash upon different industrial processes are affected by these variations.

Most coal-cleaning processes are based upon the difference between the specific gravities of coal and dirt, and some are capable of making a close 'cut' at