

until such an understanding was obtained little progress was to be expected in studying the chemistry of living matter.

By 1851 the efforts of many chemists had produced a substantial body of factual knowledge; but despite type theories and radical theories, there was no really satisfactory theory of valency which could correlate the facts and establish the interrelationships of organic compounds. In 1852 E. Frankland made the first clear statement of the idea of valency or fixed combining power of an element. This was a great step forward, and it was followed in 1858 by the work of Kekulé and Couper, who independently put forward a theory of molecular structure based on the quadrivalency of carbon and the capacity of carbon atoms for joining together in chains; they showed how molecular constitution could be represented diagrammatically in graphic formulæ and could predict the existence of isomers. That more isomers did, in fact, exist than were allowed for by this theory was, however, clear from the earlier work of Pasteur, who had shown that two optically active tartaric acids exist. This was clarified in 1874 by van 't Hoff and Le Bel, who added to the Kekulé-Couper ideas the concept of the tetrahedral carbon atom and thereby introduced the idea of space- or stereo-isomerism. With this the whole subject was placed on a firm basis, and on these theories virtually the whole of the modern science arose. Only in comparatively recent years have alterations in basic ideas of molecular structure come from physics through knowledge of the electronic structures of atoms, but even these new ideas have not altered the essential applicability of theory laid down between 1850 and 1874.

Armed with this understanding of structure, the study of the carbon compounds flourished exceedingly, and by the early twentieth century a vast number of such compounds were known and methods of synthesis and analysis had been developed in great variety. During this period, too, began the rise of the great organic chemical industry—producing dyestuffs, starting from the initial aniline dye of Perkin, explosives, etc. This rise of an industry notable for its closeness to the advancing front of a science has continued, until to-day it produces not only dyes and explosives, but also plastics, detergents, photographic materials, drugs, fabrics and a multitude of other things which we accept without question as part of everyday life—there are indeed few of the material comforts of life which do not owe something to organic chemical industry.

The twentieth century has seen, however, a remarkable development in our knowledge of chemistry in relation to living matter. During the latter half of the nineteenth century organic chemists paid scant attention to this side of their subject, and even biochemists—those concerned primarily with the nature of the processes going on in living matter—were relatively few. It is only in this century that great strides in biochemistry have been made.

From the organic chemist's point of view, this was inevitable. The materials found in living matter were too complex for him to study with success until he had mastered the groundwork and developed methods for studying carbon compounds in general. This mastery came from the work of the late nineteenth century, and as the twentieth begins we can see the beginnings of a move towards the goal of the early organic chemists in the work of Fischer,

Willstätter and others on the proteins, purines, sugars, natural colouring matters and enzymes. This movement has grown continuously, receiving enormous impetus through the development of micro-techniques enabling work to be done with tiny quantities of material; and in the past twenty-five years it has given most of the spectacular achievement of organic chemistry in the structural elucidation and synthesis of hormones, vitamins, alkaloids, natural colouring matters, etc., and indirectly of the synthetic drugs. Parallel with it have come the developments in the understanding of the finer details of molecular structure and reactivity associated with the names of Lapworth, Robinson, Pauling and Ingold. The welding together of the results and ideas emerging from these two fields of endeavour promise still more striking triumphs for organic chemistry in a future which should be as fascinating as its past.

VERTICAL MIGRATION OF PLANKTON ANIMALS*

MANY of the small plankton animals in the sea which are important as the food of fish such as herring, sprat and mackerel swim upwards towards the surface in the evening and down again to deeper levels after dawn. It is of interest from a purely biological point of view to find out what are the factors which govern these movements, and may also be useful in reaching a better understanding of the shoaling of the herring. The plankton consists of small animals of many different kinds, small jellyfish, worms and molluscs, hosts of small crustaceans and many others; they nearly all show this nightly vertical migration upwards. Since it has been developed in so many different groups of animals and must use up so much energy every day—some of them climbing more than a hundred feet—it must clearly be of profound significance in their lives. We do not yet understand its meaning and are still only in the stages of studying the actual movements of the animals in relation to different conditions of light, temperature, pressure, etc.

Hitherto it has not been possible to see animals making extensive vertical migrations in the laboratory or to experiment with them while doing so. Now apparatus has been devised which allows this to be done. A curved transparent tube of 'Perspex', of 2 in. by 1½ in. cross-section, is made to form a complete circle of 4-ft. diameter and is then mounted as a wheel; a small opening, which may be sealed up, allows it to be filled with water and the experimental animal added. The wheel is now turned so that the animal is half-way up one side; it can now swim up or down according to the varying conditions of light, etc., which may be controlled; but as it does so the wheel is turned so that it is actually kept stationary in relation to the observer. It is seen that the animal is swimming in an endless tube; it can swim up and up, or down and down for hundreds of feet, and the wheel, which is turned all the time, automatically records its speed of swimming on a recording drum. Inside the tube are small doors, some with weights and some with floats, which automatically open and close as the wheel goes round; they are always wide

*Substance of a paper read by Prof. A. C. Hardy, F.R.S., and R. Bainbridge before Section D (Zoology) of the British Association on August 10.

open at the side at which the animal is swimming and so do not interfere with it, but closed on the other side to ensure that the water turns exactly with the wheel.

A parallel tube fitted with a photo-electric cell records the light intensity at a point beside where the animal is swimming. The experiments are performed with the wheel in a small glass greenhouse and the intensity of the light varied from bright daylight to complete darkness by a series of white, grey and black screens which can be drawn over the top.

Tracings from the recording drum of the swimming up and down of different animals under different conditions were shown and discussed. *Calanus*, a crustacean, almost the size of a grain of rice and the principal food of the herring, is shown to be able to climb 50 ft. in one hour, and another larger crustacean, *Meganctiphanes*, almost an inch long, can climb as much as 305 ft. in the same time.

APPLICATIONS OF PLASTICS

AT the British Plastics Convention and Exhibition held in Olympia, London, during June 6-16, the plastics industry was given full opportunity for displaying its products and discussing the technical and practical aspects in the Convention Hall. The industry can claim considerable credit for the display. This relatively new and virile industry is one which uses its chemical raw materials in a careful and efficient manner to produce a very wide range of products and articles which are proving of much benefit to many industries to-day. They enable new assessments to be made of many old problems and processes; new values of durability, resistance to chemical attack or corrosion under atmospheric conditions, beauty and often lower-cost production resulting from their adoption. There is a large range of plastics materials available, and each one of the materials has itself an almost limitless range of applications best suited to its chemical and physical properties. There is in the lighter industries a very considerable scope for their adoption for very many uses.

The various plastics raw materials will be described first, and a few of their chemical and physical properties named. Then some of the outstanding applications for each plastic dealt with in the Exhibition and the Convention will be mentioned. Plastics materials are either moulded or otherwise fabricated into the many articles or other finished products used by the consumer, who may be the public, or the manufacturer of other products used in another industry. It should be stated here that the plastics materials referred to are the organic plastics only, but by common consent in the industry, rubber is excluded from the range.

Celluloid (or Nitrocellulose), discovered in 1865. This is the recognized pioneer material. It is thermoplastic, which means that after it has been shaped while it is hot, it is rigid when cold. But it will soften again on reheating and it can then be reshaped. Although it is the oldest plastic, it still has many uses which would not be improved upon by more modern materials, for example, table tennis balls, covering stretched over metals, such as automobile steering wheels and omnibus rails, hairbrush backs and tooth-

brush handles, etc. Its inflammability, however, necessitates its use with caution. In its sheet or rod form it is remarkably tough, while, of course, it is unaffected to a large degree by water and many chemicals.

Cellulose Acetate, discovered in 1865. This non-inflammable grade of plastic replaced celluloid for some uses where inflammability was feared. It is a thermoplastic. It came into prominence during the First World War as an aeroplane 'dope'. After that War ended, large stocks were available for utilization, when the process of converting the white powdered cellulose acetate into sheet and rod was developed. A new and relatively safe plastic was available for use in such things as lamp-shades, ornamental articles (for personal decoration, such as brooches, etc.), transparent sheet for packaging, astraldomes for aircraft, fountain-pen barrels, moulding powders, etc.

This material is extremely tough in all its forms and can be made in both rod and sheet form and as moulding material, clear, opaque or translucent (for example, tortoiseshell). Among numerous articles for consumer use made from cellulose acetate are fancy goods, door beading, drawer pulls and handles, spectacle frames, ciné non-flam film, packaging, showcards, protective eyewear.

Cellulose acetate is used to quite a large degree as the raw material for cellulose lacquers, extensively used for general decorative applied finishes. It is also used on ships' fittings, such as covering metal handrails, door furniture, etc.

Casein Plastics, first produced in 1885. This class of plastics is gradually giving way to more modern materials. It is available in sheet or rod form principally, and its present use is mainly for ornamental buttons for the garment industry, which articles are fabricated by machines from rod or sheet. It is not waterproof in the generally accepted sense of the word.

In addition to buttons, many fancy goods are made from it, such as barrels for pencils and fountain-pens, and insulators and articles for resisting low-tension electric currents. Other applications are shoe buckles, knitting pins, umbrella handles, furniture handles, combs, etc., by machining from rod or sheet.

Phenolic Plastics, developed in 1907. This type of plastics is the most extensively used range of materials at present. Phenolic plastics are thermosetting, which means that while hot they may be shaped; but during shaping a chemical reaction takes place which hardens the material in the mould. Further heating does not soften the moulding or shaped piece as in the case of thermoplastic materials. Thus, the finished articles or products made in phenolic plastics may be used for purposes where some resistance to heat is required. Phenolic plastics is only one type of thermosetting material, others being urea-formaldehyde and melamine-formaldehyde plastics (amino-plastics) as described later. The finished articles are extremely hard and, in addition to being resistant to heat, they are also resistant to a wide range of chemicals, but not to alkalis or strong oxidizing agents.

From the resins are made a wide range of products, such as moulding materials, paper and fabric laminated sheets, the more durable types of paints, and varnishes for electrical insulation, units of chemical plant as a structural material, acid-resisting floors, tanks, vats, pipework, etc. Large quantities are used for the manufacture of high-speed grinding wheels, brake and clutch linings for cars, adhesives for ply-