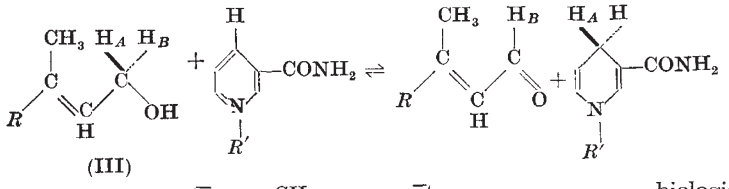
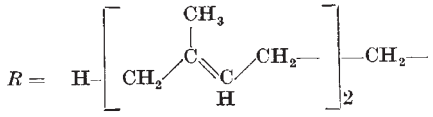
two molecules of precursor giving one of product in an apparently symmetrical manner. On detailed examination it turned out that the condensation of two molecules of farnesyl pyrophosphate to squalene was not a symmetrical process: one hydrogen atom attached to C-1 of one of the two farnesyl pyrophosphate molecules was lost in the reaction and was replaced by another supplied by reduced nicotinamide-adenine dinucleotide phosphate (NADPH). These experiments required chemical synthesis of isotopically labelled intermediates, biosynthesis by enzyme preparations, chemical degradation of enzymatic products on a micro-scale, crystallization of products in capillary tubes, and their final examination in a mass-spectrometer[1,2].

More recently, Cornforth, Popják *et al.* have shown that the synthesis of squalene from farnesyl pyrophosphate was an asymmetric process in the stereo-chemical sense: the hydrogen atom which is lost from (I) is that marked H_B in (III) and is epimeric with the hydrogen atom (H_A) removed by liver alcohol dehydrogenase from farnesol in the reaction:

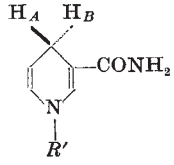


(III)



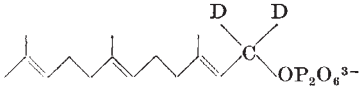
and R' = the remainder of the molecule of NADP or NADPH.

The external hydrogen atom replacing that removed from farnesyl pyrophosphate occupies also a sterically defined position in NADPH: H_B in formula (IV)[3,4]. Furthermore the insertion of hydrogen atom H_B from NADPH into squalene is likewise stereospecific; its absolute configuration was assigned recently. Thus, in squalene synthesized from 1-D_2-farnesyl pyrophosphate (V) with unlabelled NADPH:

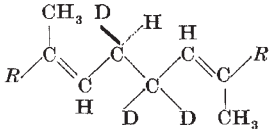


(IV)

an asymmetric centre is created (VI).

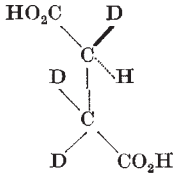


(V)



(VI)

It was shown that the succinic acid, derived by chemical degradation, from the four central carbon atoms of (VI) contained three atoms of deuterium, was optically active and had the absolute configuration *S* shown in formula (VII)[5].



(VII)

These examples serve to demonstrate the value of combining chemical and biological approach to one end, the understanding of the mechanism of enzyme action.

The work of Shell's new laboratory will be concerned mainly with similar investigations of enzymes; but research on topics of shorter-range interest will also be undertaken. The object of the basic research will be to contribute towards a complete understanding of the workings of the living cell, a goal which no longer seems impossible to achieve in view of recent advances. For example, the realization that enzymatic reactions do in general observe the ordinary laws of chemical reactivity *in vitro* opens the way for fruitful investigations in which organic chemistry and biology are blended. It is for this reason that chemists and biologists have been recruited in equal numbers to the staff of Milstead Laboratory.

The shorter-range projects will lie mainly, but not exclusively, in the application of biological chemistry to the development of pesticides and herbicides. It is known that the action of the newer agricultural chemicals, like that of the older arsenic and mercury compounds, is due to their inhibition of enzymes. By examining and observing the part played by particular enzymes in cell metabolism, and the mechanism of their inhibition, it is hoped to make easier the design of agricultural chemicals lethal to selected species and innocuous to other forms of animal life. There is also the possibility that research along these lines may ultimately point the way to biological control of pests.

The staff of the laboratory will initially number thirty, of whom 14 are graduates in physical or biological sciences. In addition to the permanent staff, a limited number of visiting workers from other establishments will be welcomed, and there will be opportunities for post-graduates to work in the laboratories for periods up to three years. Equipment covers a wide range of modern chemical and biochemical techniques, and includes a mass spectrometer, a nuclear magnetic resonance spectrometer, and facilities for radioactive tracer work.

[1] Popják, G., Goodman, DeW. S., Cornforth, J. W., Cornforth, R. H., and Ryhage, R., *J. Biol. Chem.*, **236**, 1934 (1961).

[2] Popják, G., Cornforth, J. W., Cornforth, R. H., Ryhage, R., and Goodman, DeW. S., *J. Biol. Chem.*, **237**, 56 (1962).

[3] Popják, G., Schroepfer, G., jun., and Cornforth, J. W., *Biochem. Biophys. Res. Comm.*, **6**, 438 (1961–62).

[4] Cornforth, J. W., Ryback, G., Popják, G., Donninger, C., and Schroepfer, G., jun., *Biochem. Biophys. Res. Comm.*, **9**, 371 (1962).

[5] Cornforth, J. W., Cornforth, R. H., Donninger, C., Popják, G., Ryback, G. and Schroepfer, G. J., jun., *Biochem. Biophys. Res. Comm.*, **11**, 129 (1963).

OBITUARIES

Prof. G. R. Goldsbrough, C.B.E., F.R.S.

PROF. GEORGE RIDSDALE GOLDSBROUGH, who died on May 26, 1963, at the age of eighty-two, had a long and distinguished association with King's College (formerly Armstrong College), Newcastle upon Tyne, in the University of Durham. He was a student at Armstrong College, and after graduating he held for fourteen years the post of senior mathematics master at Jarrow-on-Tyne County School. During this period he published papers in the *Proceedings of the London Mathematical Society* on the effect on ocean tides of variations in the depth of the sea and of coastal barriers. His interest in research led to his appointment to a lectureship in mathematics at Armstrong College in 1919, and he was very soon made

reader in dynamical astronomy and then, in 1928, professor of mathematics, which post he held until his retirement in 1948. He became head of the Department when Prof. T. H. Havelock (now Sir Thomas Havelock) retired, and as Sub-Rector of King's College during 1942–47, he played a most valuable part in seeing the College through difficult war-time years and those of the post-war expansion which was taking place. He was awarded the C.B.E. in 1948 for his work as chairman of the Durham University Joint Recruiting Board.

Although the dynamical theory of tides was his first and continuing interest in mathematical research and his papers on this subject appeared until 1954, mostly in the *Proceedings of the Royal Society*, the work that created most interest at the time was his theory of Saturn's rings. A theory of this unique ring system had been given by J. Clerk Maxwell in 1856, who concluded that it was composed of meteorites moving in circular orbits round the planet. The divisions in the ring system had to be accounted for, and the suggestion had been made that they were due to zones of instability around the planet set up by the satellites. In a fundamental paper in the *Philosophical Transactions of the Royal Society* (1922), which was followed by two papers in the *Proceedings*, Prof. Goldsbrough examined the influence of the satellites of Saturn on its ring system, on the basis of Maxwell's theory, and he was able to account for divisions in certain zones which were in good agreement with the salient observed features. For this work he was elected Fellow of the Royal Society in 1929. He returned to the subject again in 1941, when by a different method of solving the intricate perturbation problem, he clarified some points of criticism of his earlier work, and in 1951 he showed that, under conditions satisfied by the Saturnian rings, a pair of rings forms a stable system.

Prof. Goldsbrough had a clear, straightforward approach to any problem in hand, which, combined with his absolute integrity, led to his being much sought after as a counsellor in University affairs. He had an interest in all aspects of astronomy, and on many occasions gave lectures at meetings of the Newcastle upon Tyne Astronomical Society of which he was president during 1944–61. His wife died a few years ago, and he is survived by three daughters.

C. GILBERT

Prof. W. H. Lewis

WILLIAM HENRY LEWIS, who died on May 25 at the age of ninety-four, was educated at University College, Aberystwyth, and Jesus College, Oxford. After seven years (1894–1901) as science master at Exeter School, he joined the staff of the embryonic University College, Exeter, where he held the chair of chemistry from 1901 until 1935; he was vice-principal of the College from 1925 until 1935.

In the first few years of his tenure of the chair at Exeter, Lewis carried out research in organic chemistry and published a number of papers in collaboration with the late Dr. F. D. Chattaway, then at St. Bartholomew's Hospital Medical School. However, he soon found himself fully occupied with the affairs of the struggling young college and during the last thirty years of his occupancy of the chair devoted himself entirely to promoting the interests of the College and of his Department. During the First World War, Lewis, together with his colleagues, the late Prof. W. J. Harte and Prof. A. E. Morgan, was instrumental in the setting up of a Committee for the Furtherance of University Education in the South-west; there is no doubt that it was Lewis's devoted work as a secretary of this Committee which sowed the first seeds of growth which led, in due course, to the foundation, by Royal Charter in 1955, of the University of Exeter. Between the two World Wars much hard work was needed to get the University College fully accepted and once again Lewis was a leading member of a small group of devoted men, without whose efforts nothing lasting could have been achieved. The University College signalized its appreciation of his services by making Lewis professor emeritus on his retirement and the University by conferring on him, in 1957, the honorary degree of LL.D., a distinction which he greatly prized.

With all this, Lewis in no way neglected his Department. Starting from almost nothing, he built up a strong and active department of chemistry, with a striking record of academic successes in the external degree examination of the University of London and a sound reputation for research, which Lewis fostered by attracting good men to his staff and seeing to it that they had the facilities they needed for their work. He was responsible for the planning of new chemical laboratories, in the Washington Singer Building, opened in 1931; it would surely have pleased him to know that his old Department has now outgrown accommodation which must have seemed to many to be over-generous at the time.

Although so much involved in College affairs, Lewis found time to serve on the Council of the Royal Institute of Chemistry (1924–27) and on the External Council of the University of London (1930–35).

Lewis has rightly been called one of the founding fathers of the University of Exeter; as such he has an assured and honoured place in the history of English universities.

H. N. RYDON

Dr. G. Arnold, O.B.E.

WITH the death on August 9, 1962, of George Arnold, not only has the scientific world lost a great scientist but also we, in Africa, are deprived of a figure of outstanding merit, a redoubtable character.

Born in Hong Kong eighty-one years ago, his early education was undertaken, consecutively, in Devon, at Waldkirch in the Black Forest and at a senior school at Compiégne in France. He made full use of this early, varied education and, with his remarkably retentive memory, retained his knowledge of these languages throughout his days. After a spell of clerical work in London he commenced his scientific career at the Royal College of Science, and followed this with an appointment in the Department of Cytology and Cancer Research at the University of Liverpool.

In 1911, at the age of thirty, he was appointed to the curatorship of the ten-year-old Rhodesian Museum in Bulawayo, which eventually expanded, through his leadership, to become the National Museum of Southern Rhodesia and, largely through his investigations, an institute of international repute. Director of the Museum until 1947, he was for many years the only zoologist (in the wide sense) on the staff. Always outstandingly neat, a rare gift for a museum specialist, he was adept at casting reptiles and fish, adding all the intricate finishing touches himself.

Apart from building up vertebrate and insect collections his primary scientific interest was in the Aculeate Hymenoptera. Probably his earliest publication was a joint paper with J. E. S. Moore, director of cancer research. This was "On the Existence of Permanent Forms among the Chromosomes of the First Maiotic Division in Certain Animals", published in the *Proceedings of the Royal Society* (1905). This was followed by papers on chromosomes in *Hydrophilus*, on ovigenesis and on digestion in *Planaria*, on blood, epithelia and chondriosomes, the last of these cytological articles in 1912. Then, in 1912, Arnold read a paper to the Rhodesia Scientific Association on the "Foods of Ants" and afterwards his published works were mainly devoted to Hymenoptera. His first major entomological work was "A Monograph of the Formicidae of South Africa", published in the *Annals of the South African Museum* (1914–26). This was followed by "The Sphecidae of the Ethiopian Region" (1922–31) and "The Pompilidae of the Ethiopian Region" (1932–37) in the