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Edited by
JOHN ENOGAT



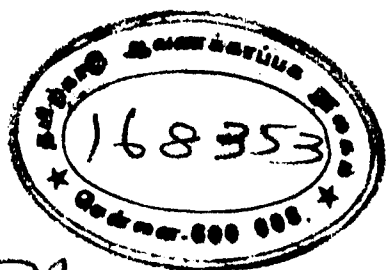
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We are indebted to the Editors of the "Proceedings of the New York Academy of Sciences," and of "Endeavour," for permission to reprint articles by Geoffrey Gorier, and Sir Lawrence Bragg, respectively. Some of the short pieces have appeared in a somewhat different form in "World Review."

FOREWORD

THIS is the first number of a new series of Penguins which will attempt to give the general reader an inkling of what is going on in the world of science. The volume of technical scientific writing is enormous. In the last few years before the war, some 30,000 scientific periodicals were published every year; they contained over half a million separate articles, in all the languages of the writing world. No one man, however much he devoted himself to scientific studies, could hope to deal with such a mountain of print; and the general reader would be bold indeed if he tried to penetrate the jungle without a guide. But everyone recognises only too clearly that out of this busy and uncomprehended world there may emerge from time to time new discoveries which profoundly affect our daily life: ideas, for instance, like that of evolution, which appear to challenge man's centuries-old religious concepts, or new technical achievements such as penicillin and the atomic bomb which alter the basic material framework of our civilisation.

Penguin Science News will be at least some sort of a guide into the jungle; it would be presumptuous to claim that it will never miss any of the significant developments, but we hope to be successful in noticing and describing the most important.

The form which the successive numbers of Penguin Science News will take will not be rigidly fixed in advance. Some numbers will, like this first one, contain articles of various lengths, and on many different topics. Others will be organised around some single theme. For instance, the second volume, which will be ready shortly, is devoted entirely to atomic energy, and has been written by a group of physicists who have been working in the Los Alamos team in the United States. Again, many of the articles will be original, but some, like Sir Lawrence Bragg's article on "Metals" in this number, will be reprints

When seeds of wheat, barley or oats germinate, they send up a tender hollow spike called the coleoptile, inside of which, rolled up as neatly as a business man's umbrella, are the first true leaves. Charles Darwin, with his remarkable nose for interesting biological material, soon discovered how very sensitive this coleoptile is to external influences. If it is grown in the dark, it need only be exposed to sunlight for a fraction of a second in order afterwards to curve towards the direction of the light. Or if it is placed on its side for a few minutes and then put up again, it will presently be found to be curving to one side, so that if it had stayed lying down, the tip would have been curving up into the vertical position. Or again a tiny nick in one side will start it curving towards the injured side. If the extreme tip, about one millimetre long, is cut off, the growth of the whole shoot stops for a time. This delicacy of response is due to the growth hormone, as was shown by the following experiment, carried out in Hungary some twenty-five years ago. Cut off the extreme tip of the coleoptile, and stick it on again, with a drop of glue, just a little one-sidedly (see Fig. 1). The result is

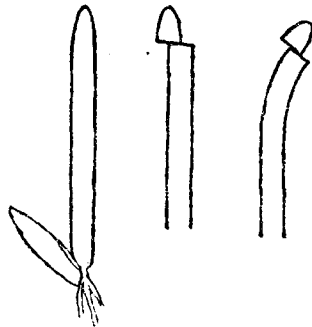


FIG. 1

Left : Intact oat seedling.
Centre : Tip of coleoptile removed and replaced slightly to one side.
Right : Curvature resulting, two hours later.

that the shoot curves away from the tip. It is in the tip that the hormone is produced, and because it can now travel down only one side of the coleoptile, that side grows faster than the other side, causing a curvature. If the tip, after cutting off, is placed on a little block of gelatine or agar jelly, the hormone passes out into the jelly, and when this in turn is placed on one side of a freshly de-tipped coleoptile it makes it curve just as the tip did. In Fig. 2 a row of such coleoptiles, treated

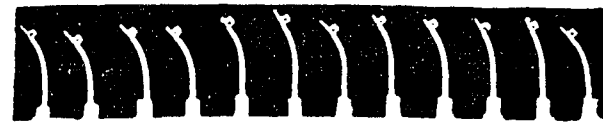


FIG. 2

A row of oat seedlings with tips removed and blocks of agar jelly containing growth hormone applied to one side. The roll of true leaves, protruding from inside the coleoptile, is used as support. Photographed 100 minutes after the blocks were put on.

with blocks of agar containing growth hormone, is shown. The experiments must be made with only the dimmest red light, since otherwise the curvature of the plants towards the source of light will interfere with the curvature due to the tip or jelly block. They must also be done in a room with high humidity to prevent drying out of the cut surface of the plant.

Reasoning from the abnormal, it is deduced that the normal growth of the coleoptile is due to the distribution of the growth hormone equally on all sides. The reason why growth stops when the tip is completely removed is because the source of hormone has been removed. The sensitivity to light and gravity, and also to injury, are explained in similar ways. Exposure to light from one side makes the hormone move across the tip towards the shaded side, so that the shaded side grows faster and the shoot curves towards the light. When placed horizontally an excess of the hormone flows toward the

lower side, causing more growth on the lower side and hence an upward curvature. An injury which prevents the passage of the hormone downwards naturally slows up the growth of the part below it. All these deductions have been proved by direct experiments, many of which were done in Holland.

These processes in the coleoptile also take place in all growing shoots, although not always with such great speed and sensitivity. But everyone knows how a potted plant in the window must be kept turned around so that it will not curve towards the window, or how a growing shoot (especially a tomato) if knocked over by wind or rain, will curve upward near the tip. Because they control growth, these hormones have been called "Auxins," a word from the same Greek root as augment, auxiliary and auction.

Very extensive chemical work was necessary before the hormone could be prepared in pure form. Coleoptile tips could not possibly be used, for the amount in them is so small that it would have taken several acres of plants, each of which would have to be carefully de-tipped, to get as much of the pure hormone as would lie on a pin's head. Fortunately it was discovered that much richer sources exist. Human urine, yeast, and cultures of certain fungi and bacteria contain the hormone in relatively large amounts, and it was from these, as well as later from wheat germ, that the pure substance was eventually obtained. Synthetic preparations which have the same effects have subsequently been put on the market, and are to be had very reasonably.

The control of growth by auxins is much more all-pervading than the above experiments would suggest, for they deal only with simple growth. Many other important phenomena in the life of a plant are under auxin control. One is the development of buds. When a growing shoot is pruned, as every gardener knows, it is usual for the first bud below the cut surface to sprout very quickly. This bud had always been able to develop

but it did not do so earlier because the rapidly-growing bud at the tip prevented it. Formerly such prevention of the growth of one bud by another was thought to be due to "withdrawal of sap" by the growing tip. We now know that it is due to auxin produced by the tip. When buds develop they produce far more auxin than is needed for their own growth, and the excess diffuses down into the stem below. Here it has the curious property of preventing the development of the younger buds. Thus, so long as the growing tip continues to produce auxin it acts as a bully, preventing the smaller buds from pushing up their heads. The explanation of this strange paradox, whereby a substance whose normal effect is to make growth can in certain places inhibit it, has not yet been found. But about the facts there is no doubt.

Another important function, controlled by auxin, is the formation of roots on shoots. In the early stages of the hormone research it was found, by an experimenter in Java, that the formation of roots is controlled by a hormone, but this was at first thought to be a special root-forming substance. Only when attempts were made to purify it was it gradually realised that it is the same substance as auxin. There may be other substances collaborating also, and a special root-forming substance may still be one of them, but in a very large number of plants it is sufficient to apply pure auxin to a shoot in order to have it develop roots at the base. Cuttings which have developing buds on them get a supply of auxin from the buds, and this travels through to the base, there producing roots. Naturally the formation of roots on cuttings is something which it is very important to control, and this has been the principal commercial application of auxins so far. Plants which are "easy to root" produce larger root systems than normal, when treated with auxin, as well as forming them sooner. Plants which are "hard to root" can often be induced to root by auxin treatment. Some

cuttings of white pine, one of the hardest of all plants to root, are shown rooted by auxin treatment in Plate 1. Roots are also formed by auxin treatment on bulbs, tubers, corms and other parts.

Curiously enough, although auxin promotes the formation of roots, the actual growth of the formed roots is rather strongly prevented by it. Roots immersed in auxin solution may be shortened and thickened, often producing many branches. It is, from a grower's point of view, therefore, not advisable to apply auxin after the roots have appeared. Also if the auxin solution is too strong there may be other bad effects, so that careful control of the strength is necessary. Instructions covering the best concentrations to use for different plants, as well as the best times in which to take cuttings, are generally provided with commercial auxin preparations. In some cases these are based on the accumulated experience of a number of laboratories or test stations, in others it is not clear on what they are based.

If seeds are treated with auxin during their time of germination, they will in many instances react like stems, and produce extra roots, which subsequently enable them to develop more rapidly than normal. In the case of oats the plants from treated seeds keep ahead of the ordinary plants, and though they do not flower any sooner, they produce larger heads. In Plate 2 are shown the heads of ordinary plants (at top) and of plants from the same seed-lot, grown under the same conditions, from auxin-treated seeds. The latter are about 50 per cent larger. Unfortunately the use of this method on an agricultural scale has given somewhat erratic results, and the conditions will have to be more carefully worked out before it can be generally recommended.

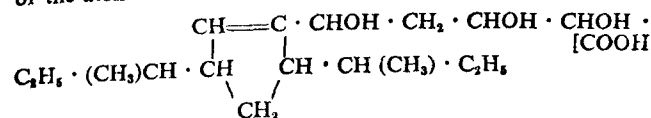
Somewhat similar to the prevention of bud development is the prevention of fruit drop. Fruits fall from the tree because a layer of cells grows across the base of

food solution, they will not grow for long unless a little vitamin B₁ is added. Only traces of the pure vitamin are needed, but without them growth stops completely. Freshly rooted cuttings, or some seedlings which have only poor root systems, therefore benefit from application of B₁. This can be done by watering with a dilute solution of the pure substance. Part of the good effect of animal manure may be due to the fact that it is rich in B₁. A few plants, notably gardenias and camellias, which grow slowly under ordinary conditions, can be accelerated by watering them with the vitamin. Nevertheless general application to crop plants has not shown any reliable effect, and the more carefully controlled the experiments are the more negative are the results. We can only suppose, and this is supported by direct experiments, that one reason why certain plants produce good crops is that they produce ample vitamin B₁ for their own needs. There is no justification for the popular idea that there is anything harmful in "chemical" fertilisers, or that they "poison the soil" in any way. Indeed, organic fertilisers like animal manure are largely converted into simple "chemicals" by the bacteria in the soil before they are taken up to any appreciable extent by the roots of plants.

There are other plant hormones which have been less studied. The growth of new tissue after wounding, and the formation of flowers, are both controlled by hormones, but less is known about these as yet than about the auxins.

The plant hormones are an excellent example of the rule that any research, however apparently "academic," may prove in the long run of great interest. It is hard to imagine anything more "useless" than the painstaking study of the curvatures of oat seedlings in a dark room, yet the many applications of this field of science cannot be foreseen and may have a tremendous influence on the oldest and most fundamental business in the world, the growing of plants.

The chemically-minded may like to know the arrangement of the atoms in Auxin. Auxin A is:



One of the synthetic hormones commercially available, which produces the same effects on the plant, is β -indolyl acetic acid.

HOW THE PHOTOGRAPHIC PLATE WORKS

THE photographic plate or film is a thin layer of gelatine containing small crystals of silver bromide, spread on a sheet of glass or celluloid. The basis of the idea behind its working is that when light falls on a silver bromide crystal it decomposes it into metallic silver and bromine. The silver is deposited in the gelatine and cannot be washed out on fixing the film, while the salt silver bromide itself, and the bromine, can be removed. Wherever light falls, therefore, insoluble silver will be deposited, and wherever it is dark nothing happens; so that when fixed the negative appears dark wherever the view was bright, and transparent wherever the scene was dark with deep shadows. Since each salt crystal is a little photo-sensitive unit in the process, clearly the grain or fineness of detail of the film depends at least in part on being able to produce smaller and smaller silver bromide crystals closely packed together in the gelatine.

But two puzzles had until recently been holding up further advance. One was the short exposure time, perhaps one twenty-fifth of a second only, which is all that is required to take a snap. In some way the silver bromide in the gelatine must be much more light-sensitive than it is in the bottle, where it takes hours of exposure to deposit enough silver even to be visible under the microscope, though on the other hand the exposed film actually shows no silver till after development; only a sub-microscopic change has occurred. What this change is, and how the developer makes it visible, was the second puzzle. The trouble was that photography had begun in a semi-empirical accidental sort of way, and until a proper understanding of what was going on could be obtained, the production of super-sensitive panchromatic film, film for night and colour

photography, remained very difficult, a matter of guess-work only.

The problem was to a great extent solved by the work of Dr. Sheppard in tracking down the sensitiser in the gelatine which made the silver bromide so much more light-reactive, an advance which enabled Dr. Gurney and Professor Mott, of Bristol, to build a complete explanation of the whole process. It was found that the silver bromide crystals in gelatine were not as pure as originally thought, but contaminated with tiny specks of another silver compound, silver sulphide, stuck about on the surface of the crystal. This impurity had got in accidentally during manufacture, and very fortunately so, as we now see. Its effect was simply this. When light falls on a photo-sensitive substance such as silver bromide, it releases the negatively charged particles of electricity called electrons, which wander aimlessly in the crystals until they meet with an impurity—normally quite a time in pure silver bromide. But in the film every crystal has specks of impurity, and the electrons move to these points in a flash, and charge them with negative electricity. Now the silver bromide itself is a compound made by silver and bromine atoms lying side by side, the silver having given one of its electrons to the bromine so that the net effect is of negatively charged bromine atoms (bromide ions) and positively charged silver atoms, or ions, lying side by side. These positive silver ions are attracted by the negative specks of impurity, and a few of them accept electrons again and deposit as atoms of pure silver in a kind of sub-microscopic electro-plating. It is very similar to a process like the rusting of iron: very pure iron will not rust at all, but as soon as specks of impurity are allowed on its surface, rust begins to form.

The exposed film before development thus contains silver bromide crystals studded with sub-microscopic groups of silver atoms, each group a weak spot in the crystal and a nucleus for the deposition of more silver when the crystal meets the developer. Each nucleus

oestrogens, present in women, depress its growth and decrease its size. Since it is an important part of the male sexual apparatus, these facts are not surprising.

Huggins applied this new knowledge to the cancer problem by arguing that, since the cancer cells were derived from normal prostate, they might very well be subject to the same controlling forces. And so indeed it has proved. If he injects oestrogens into men with cancer of the prostate, in many cases the growth of the tumour is arrested. A rather better method is castration: the loss of the testicles results in an absence of androgens, and the tumours cease to grow and may even shrink, as shown by X-ray photograph. Of course, in both methods there is a loss of sexual power, and the oestrogen injection has certain other disadvantages also, but for an elderly man it is a small price to pay for a dramatic change. Within a few days of starting treatment, the patient improves enormously; the severe pain is relieved, the appetite returns, the anæmia clears up. Unfortunately this great improvement is not maintained in all cases, and in such the treatment can only prolong life and make it pleasant for a limited period. In rather less than 5 per cent of cases it has no effect at all. Why this is so is a matter for further research. What is clear is that the treatment offers great hope of improvement or cure in most cases of prostate cancer.

But why does the treatment work only for cancer in the prostate? To understand that it is necessary to realise that cancer is not a single disease, but a group of illnesses sharing certain similarities. In the normal body all the cells of any tissue or organ, the stomach for instance, grow at the same slow rate and perform their allotted functions. Suddenly in one corner or the other there appears a group of rapidly growing, rapidly dividing cells, while their neighbours remain calm. These very active cells are derived from "calm" ones which for some unexplained reason have gone "mad," and instead of remaining soberly to form an organ of the usual shape,

spread out in all directions and build a swelling tumour. If these wild cells are dividing very fast they will invade surrounding tissues of the body before the body can do anything about it; and small groups of cells will break off and float away to join up somewhere and form fresh, secondary tumours in other parts of the body. The faster they grow, the less they perform their normal functions, and the less amenable they are to chemical influences. They take food from the tissues and organs and create a kind of internal starvation so that the person wastes away.

The exact form that cancer takes depends on the particular place and kind of the primary tumour, and how fast it grows. Some never fragment and spread to other parts of the body and are therefore an easy matter for the doctor to treat. That is also the point of attack the surgeon prefers—to be able to cut out the cancer while it is yet young, before it has had time to start secondary tumours elsewhere, often in inaccessible places. Some tumours are sensitive to radium or to X-rays and can be killed by a carefully controlled dosage with these; but care is needed, because all living things are ultimately destroyed in this way, though dividing cells are especially susceptible.

These methods are good: many people have been cured of cancer by their application. But they are only of use in the early stages of the disease, which means that people who think they may have cancer should see their doctor without delay: in this way they have good prospects of recovery.

But up till now the precise causes which make some cells run wild, and the ways to control them when they have, are completely unknown to medical science. It seems likely, if Huggins' results are any guide, that each sort of cancer may have its own controlling substances, and working along these lines, Lipschütz, in Chile, has an interesting line on the causation and treatment of benign growths of the womb in women (fibroids). He

has been experimenting on guinea-pigs, and finds that he can produce these fibroid tumours in guinea-pigs by continuous dosing with the feminising substances or oestrogens mentioned before. Tumours so produced can be caused to go away again by treatment with male substances (testosterone), with chemical substances extracted from the cortex of the adrenal glands (desoxycorticosterone), or with the hormone of pregnancy (progesterone). In other words, it is rather the reverse of the Huggins idea, because applied to the other sex.

So far this method has had no test on women, and when it comes to be tried on human cases of disease it may prove to be failure, as so many "cancer cures" before it. At least it does not claim to be a cancer cure-all, as have so many medicines loudly praised by their inventors. The truth is that apart from the special case of the prostate, there is no medicine to cure any form of cancer at present. Some of the confusion in this matter has arisen because testing out the value of a proposed medicine is no easy matter. One must try it on a large number of cases, and compare the results with those from a group of people suffering from the same disease in exactly the same way but receiving no treatment. So often after good results on twenty or so sick persons, the doctor will write an enthusiastic report, for which there is no justification, though one may sympathise with him to some extent. Some patients may recover by themselves, others may be misdiagnosed, others again may be benefiting from some chance factor—a change of diet, for instance, of which the doctor is not aware. The only way to be certain is to try two or three hundred cases and compare the rate of cure with that in another group of people ill in the same way, living under the same hospital conditions, treated exactly as the first group, except that they get none of the medicine under test. Does the medicine make any difference at all? There are all kinds of catches in this work: it is a skilled business. It means that the average practising doctor

is not in a position to pronounce on a new treatment; it means that the relatives of the patient cannot tell one way or the other about the value of the new treatment on their sick person. If he or she gets better, well, that's good luck; if they die, misfortune; one can only tell by studying a group.

For the present, then, in treating cancer we must rely on early diagnosis and the crudity of surgery. But there is a bright future. In universities all over the world research is going ahead on the chemical ways in which living things work. Those chemical reactions which make a few cells go mad, those substances to set them straight and sober again—maybe their discovery is just around the corner.

JAPANESE CHARACTER

GEOFFREY GORER

SUPERFICIALLY, contemporary Japan would seem to be the most paradoxical culture of which we have any record. How can the same culture—often the same persons—prize and perform the elaborate, highly ritualised and symbolic Tea Ceremony, with its elegance, calmness and poetry, and indulge in the almost unbelievable savagery, lust and destruction of the rape of Nanking? Go out by the hundreds of thousands to admire the wild cherries in bloom, or to listen to the cicadas, and at the same time systematically and consciously force whole populations into the degradation of drug addiction? Hold serious lyrical poetry competitions, in which the Emperor is a contestant, and build a shrine for the Living Bombs—three soldiers who fastened themselves to a high explosive bomb? Develop some of the most refined graphic arts we know, and yet have a major portion of the work of their most famed artists so pornographic that much of it has never been seen in Europe or America? Adopt the most elaborate complications of our modern society and yet retain a view of the world—part political, part religious, part social—more consonant with an isolated and primitive tribe than with a major industrial nation?

It was an attempt to explain these paradoxes that led me to undertake the research which I shall attempt to outline here. I have tried to isolate theoretically those aspects of the Japanese character-structure and culture which might account for these and other paradoxes and which can be hoped to have some predictive value in dealing with the Japanese. To do this I have been forced to simplify the total picture enormously and to omit large portions of the culture; in particular I omit

any but passing mention of the politico-social structure of power, and of yet another paradox—that Japanese society and economy have very little similarity with the other great Asiatic societies and culture areas (China, India, Java or Egypt), but far more resemblance to Europe, particularly mediæval and Renaissance Europe; nor can I elaborate on the strange socio-economic parallelism between the capitalist-imperialist policies and ideologies of Feudal Japan and Nazi Germany. In a total picture, of course, these points would have to be given full consideration.

Probably I should have started with an apology and an explanation. I have never been in Japan; I cannot read Japanese; I have no special qualifications for discussing Japanese culture. The research that I undertook at Yale was in the nature of a methodological experiment; an attempt to interpret culture by the application of fairly rigid theoretical formulations to such data as were available in books written in European languages, supplemented by interviews with some two score informants who were either wholly or partially Japanese, or who have had prolonged and intimate knowledge of Japanese life. Since such validity as can be granted to the conclusions depends on the acceptance of the methodology, you will perhaps allow me to outline my basic postulates in some detail.

These postulates are derived from the disciplines of social anthropology, psychoanalysis and stimulus-response psychology, and represent a first attempt to construct a unified theory of social science. These formulations are inevitably tentative. There are twelve of them.

1. Human behaviour is understandable: with sufficient evidence it is possible to explain any observed behaviour, however incongruous isolated items may appear.
2. Human behaviour is predominantly learned. Although the human infant may be born with some instincts and is born with some basic drives

- whose satisfaction is necessary to its survival, it is the treatment which the infant undergoes from the other members of the society into which it is born, and its experiences of its environment, which are of preponderating importance in moulding adult behaviour. (In this context I may as well state that I have assumed consistently that the genetic peculiarities of the Japanese do not involve any inherent psychological differences from other groups of human beings.)
3. In all societies the behaviour of the component individuals of similar age, sex and status shows a relative uniformity in similar situations. This is equally true in unformulated and unverballed situations.
 4. All societies have an ideal adult character (or characters, depending on sex and status) which is of major importance for the parents in selecting which items of their children's behaviour to reward, and which to punish.
 5. Habits are established by differential reward and punishment, chiefly meted out by other members of the society.
 6. The habits established early in the life of the individual influence all subsequent learning, and therefore the experiences of early childhood are of predominant importance.
 7. The chief learning in early childhood consists of the modifications of the innate drives of hunger, optimum-temperature seeking, pain-avoidance, sex and excretion, and of the (probably learned) drives of fear and anger (anxiety and aggression) which are demanded by the adult members of the society; consequently a knowledge of the types of modifications imposed, the means by which they are imposed, and the times at which they are imposed, is of major importance in understanding adult behaviour.

8. Since everywhere it is predominantly the parents who reward and punish their children, the attitudes of the child to his father and mother, and, to a lesser degree, towards his siblings, will become the prototypes of his attitudes toward all subsequently met people.
9. Except in situations of the greatest physiological stress, adult behaviour is motivated by learned (derived, secondary) drives or wishes superimposed upon the primary biological drives.
10. Many of these wishes are unverballed or unconscious, since the rewards and punishments which established the habits of which these wishes are the motives were undergone in early childhood, or because the verbalisation of these wishes was very heavily punished; as a derivative from this hypothesis, people frequently cannot verbalise their motives, which have to be deduced from the observation of what satisfactions are actually obtained in a given situation.
11. When these wishes, acquired through early training, are shared by a majority of the population, some social institutions will eventually be evolved to gratify them; and existing social institutions, and those that are borrowed from other societies, will be modified to congruence with these wishes, in so far as this is possible without impeding the gratification of the primary biological drives.
12. In a homogeneous culture the patterns of superordination and subordination, of deference and arrogance, will show a certain consistency in all spheres from the family to the religious and political organisations; and consequently the patterns of behaviour demanded in all these institutions will mutually reinforce each other.

On the basis of these assumptions I constructed a very detailed questionnaire on childhood training (the possible variants of the treatment of infants are limited)

which I administered to my informants. I sought for, and obtained, answers in the most concrete possible forms. In other words, I collected from my informants not generalisations but reminiscences of concrete family situations—in the case of Nisei and Japanese autobiographical reminiscences. The generalisations are my own. I listened to those which my informants insisted on making, but did not necessarily accept them. When the majority of informants reported similar behaviour from different social contexts I assumed this to be the pattern. When an informant reported practices not reported by others, an attempt was made to check this information; if no check could be obtained the information was not incorporated, on the theoretical ground that the individuals observed were probably aberrant. Simultaneously, I read the majority of the available books in English, French and German, to build up a picture of the existing adult society and to search for confirmations and negations of the hypothesis deduced from the interviews.

Owing to the fact that I could interview only people in the north-eastern United States, my sample produced a definite distortion. The vast majority of my information deals with people living in the cities, and of middle and higher income groups. I have no consistent information at all on the urban proletariat, and my information on rural society is almost entirely dependent on the book and conversation of Dr. John Embree, whose study of the village Suye Mura is incidentally the only book on contemporary Japan using modern sociological concepts and techniques.

I will now proceed to outline summarily the main patterns of Japanese childhood training, and then attempt to explore the development of some of these themes in adult social life.

Almost without exception the Japanese welcome children, especially male children. Much fuss is made of the new baby, especially if it is a boy, and it quickly

becomes the focal point of the household. For the first month the baby is held in the arms of its mother; after that it is carried spread-eagled on the back, with a double sash holding it under the arms and under the bottom. In winter a special kimono covers mother and child; such fresh air as the child gets is obtained by bending its head sideways.

The oldest child is carried entirely by its mother; but subsequent children will also be carried by older siblings. This is the one domestic task which is imposed on boys up to the age of about ten, if there are no sisters to carry the new baby.

During the first two years of life the child is on the back practically all its waking hours. When on the back the child has to learn to adapt itself passively to the often violent movements of its carrier; a mother will do arduous household tasks, or a sibling play tag or hopscotch, while burdened with a baby.

The Japanese baby is, if anything, over-fed. It is not only given the breast whenever it shows any signs of wanting it, but the breast is also often offered to it before it shows any signs of hunger. Also from a very early age the child is given a little solid food, at first pre-masticated by the mother and spat into the baby's mouth; a little later finely ground rice and gruel are given directly. Frequently, when the baby is fed solid food, the mother's hand is held over its mouth to prevent re-gurgitation.

Normally the child is weaned shortly before the birth of the next baby, generally between the age of two and three. Weaning is apparently gradual and accomplished entirely by verbal prohibitions and exhortations; superficially it would seem to be very slightly traumatic. Children are allowed artificial pacifiers if they desire them. They also are allowed to put any loose objects into their mouths; and thumb-sucking, though uncommon, is not interfered with.

According to Occidental standards, Japanese babies

are over-protected against cold. They are dressed in several layers of clothing. In winter the warmth of the carrier's body is held in by the special kimono which covers mother and child. The child sleeps under warm quilts, and one of the chief causes of infantile accidents is being smothered with the quilts.

From birth, the Japanese baby is restricted in its movements. The constricting position in which it is carried has already been described. If the child fidgets or cries while on the back, the carrier joggles from leg to leg until the baby quiets down. This shaking is described as rhythmic, and therefore may have a soothing quality; but since it is sharp and sudden—a sort of jumping from foot to foot—it is almost certainly predominantly painful, and the child quickly learns that any expression of pain or anger or any undictated movement is dangerous. When the baby starts to crawl it is forcibly restrained. The Japanese house is dangerous for a baby, and is conceptualised as even more dangerous than it is; a baby can break the paper walls or burn itself on the open charcoal burner; and it is believed that even the weight of a baby may be too heavy for the raised joists which support the house. These joists follow the shape of the white mats; and as soon as a baby can walk he has to learn to avoid stepping on the joints between the mats. One of the greatest crimes that a child can commit is to step on the sill, for that, it is said, would risk having the whole house put out of shape; if a child of four or five does so, he may suffer the very severe punishment of having the cautery, MOXA, burned on his back. The Japanese child has to "learn" its home completely, until, even when burdened, there is no risk of stepping where he should not; a mistake involves not only the possible incidental pain of falling or being burned, but also severe punishments from the parents.

Besides learning where to walk, the Japanese child from the second half of its first year onward is carefully

taught how to sit. The correct Japanese sitting position is almost certainly painful for young children (some people consider it the chief cause of the very general Japanese bandy-leggedness), especially when it has to be maintained without any fidgeting or unnecessary movements of the hands or head; but the absolute standard is aimed at and nearly attained in very early life, partly by reward, partly by positively-phrased exhortations, and partly by shaking, pinching and other punishments. This strongly sanctioned early training in keeping quiet in uncomfortable positions is reflected in adult life in the often noted impassivity (inscrutability) of the Japanese; they have been strongly trained not to give physical expression to their emotions. Incidentally, this impassivity and physical restraint is the first item of behaviour to be reversed under alcohol.

Further bodily training is given to Japanese babies from the age of about six months, in bowing to people to whom courtesy is due; the mother or carrier puts her hand behind the baby's neck or upper back and pushes the top part of the baby's body forward, with the appropriate expressions. By the time a child can toddle it should be able to make these salutations spontaneously, or at a word from its guardians.

There is a considerable aura of fear and anxiety about the etiquette of sitting and bowing. Parents are anxious to avoid the criticism which will be made to them if the child does not behave appropriately; and the child is frightened that it will be punished by its parents if they are criticised.

In the life of Japanese children, the most consistent and most severe aspect is cleanliness training, training in control of the sphincter. For about the first four months the child has a heavy cloth diaper (not paper, which is used for the disposal of all adult excreta) which is changed relatively rarely, though the child is regularly washed in hot water. After four months the child is held out over the balcony or road at frequent intervals,

either when it cries, or when its guardian considers the time is ripe; any lapse from cleanliness is punished by severe scolding, the mother's voice expressing horror and disgust, and often also by shaking or other physical punishment. The training is meant to be complete by the time the child can toddle on to the balcony and all informants agree that this ideal is obtained.

Except those Japanese who have accepted Western standards of prudery, or in those situations where Western disapproval might be manifested, Japanese parents are extremely permissive towards infantile expressions of sexuality. Even when these are directed towards adults they are usually treated good-naturedly, as funny; the only negative sanction used is mockery, but, for the Japanese, this has very considerable emotional importance.

Physical modesty, as an absolute, is not inculcated by the Japanese (except that they should not be seen defecating). Immodesty is defined as a greater exposure of the surface of the body than the situation calls for. Verbal modesty is treated similarly; children know obscene words and there is no taboo on their using them, except in unsuitable circumstances. No attempt is made to hide from children the "facts of life."

Somewhere between the ages of three and five—depending on when the next baby is born—the Japanese child finds that he has to adjust to a new picture of the world. It is expected that the Japanese child will share the attitudes of the rest of the family to the new-born younger sibling, will accept it as the centre of the family picture, willingly give way to it, always be ready to play with it and listen for its first intelligible sounds. The child is expected to take a quasi-parental attitude towards the new baby, looking on it as a toy, rather than as a rival.

Whether a younger sibling hastens the event or not, somewhere around the age of four the Japanese child has to pass from babyhood to childhood. In infancy

and babyhood boys and girls are treated alike or nearly alike (for it is possible that girls never get quite as much affection and attention); they are the centre of attention, constantly played with and gratified and talked to, provided they follow scrupulously the rules of cleanliness and politeness, and respond passively to the adults around them. As they enter childhood, however, differential demands are made on boys and girls, and different behaviour insisted on. The girls must still remain passive, but they are no longer the centre of attention, and are no longer so much rewarded for their passivity; instead they are severely punished for any lapse therefrom, for any gesture of self-assertion that they may make. As they grow up, the restrictions on their movements, gesture, posture and language are constantly increased, reaching their culmination at marriage. There seems to be a conscious fear among Japanese parents that their daughters will grow up inadequately feminine; the greatest praise that can be given to a girl or her parents is that she is *ONNARASHII* (like a girl) or *OTONASHII* (quiet and inconspicuous); the term *OTOKORASHII* (like a boy) is the worst insult that a girl can receive, and the most humiliating that a parent can hear. It is worth noting that the converse is not true of boys; even the most effeminate and cowardly boy is so superior to any woman, that there is no equivalent term for "sissy."

Realistically, there is good reason to fear that a girl will resent the social rôle laid out for her, and will try to adopt the rôle of her brother. Although no psychological change is demanded of her, she is fairly abruptly shifted from being the centre of family attention to being the most insignificant member of the household. She learns that she has to give way immediately and unquestioningly to any demand or request made by any male (in babyhood even a girl baby is deferred to); that she has no claim for preferential treatment in any sphere; and that she also has to give way to all older females.

She has many duties, few rights or privileges. Although her physical movements are controlled, she is allowed relatively free expression of her emotions; in contrast to her brother, the Japanese girl is volatile, easily changing from sorrow to gaiety, from tears to laughter, without reproof.

The world of the growing girl is not particularly indulgent, but it is self-consistent, and demands from the girl (a modified) continuation of her previously rewarded habits of passivity. The readjustment of the boy is much more complex.

Put briefly, the boy must learn to adapt differentially to two contrasting worlds. Towards his father, his elder brothers, and later his teachers he must preserve the same attitudes of passive compliance. There are absolutely no situations in which a boy must not show complete obedience and compliance to males superior to him in age or status; any lapse therefrom is immediately and drastically punished. But, because he is a male, he finds himself in a position of dominance over all women, practically without respect to age or status. Because he is a boy he has automatic precedence over all the females in his household; they must and do give way to him; demanding and aggressive behaviour, which is so heavily punished when directed towards other males, is heavily and constantly rewarded when directed toward females.

This dominance of a boy of four or five over his female relatives is carried to very great lengths. In a dispute with a sister both parents will insist on the girl giving way; in a dispute with the mother, the father will back up the son. It is only the boy's physical strength which limits the aggression which he may display towards his mother, nurse or sister. The child learns that aggression, directed towards the proper persons, always pays. If the boy wants something that the mother refuses (or if he has something which the mother attempts to take away) he will go into a temper tantrum, lying on the floor,

kicking and screaming. The mother will first try to calm him by calling him pet names and giving words of praise; if this fails she will offer sweetmeats; next she will try to cajole him with promises of future indulgences. But none of these devices may be successful; the boy may refuse to be diverted; and then he may strike and insult his mother, may kick her and punch her and bite her. The mother begs for mercy, begs him not to hurt her; she may not use her greater physical strength to resist her son (at any rate in the urban middle or upper classes, where the economic value of a wife is so much less than in the country or among workers) for then her husband may punish her. As a final humiliation, the boy may destroy his mother's hair-do, and break her precious hair ornaments; but usually she will have given in to the little fellow before such a pitch is reached.

This excessive permissiveness toward boyish aggression is, as far as I know, unparalleled in other societies; but all informants agree that it occurs in this exaggerated form, and give detailed and circumstantial reports.

Although his mother is the one person against whom the Japanese boy is permitted to show almost unlimited aggression, and to whom he is required to show practically no formal respect, she nevertheless still remains the source of all his major gratifications; and the strong emotional bond between the mother and her son is normally never completely destroyed.

These violent temper tantrums stop when the boy is six or seven. At that age the boy will be going to school, and there, or anywhere else outside the home, all physical expressions of violent feeling are punished, laughed at and stopped.

The one other point which perhaps needs documentation is the early development and excessive importance given to the symbolic punishment of mockery. In all societies, being laughed at is felt to be unpleasant; in Japan, however, it is the most drastic sanction of all, more dreaded by most than the greatest physical pain and

deprivation. In earlier periods, when a samurai gave his note to return a borrowed sum, the only guarantee affixed was the permission to be laughed at in public in case of failure. The mainspring of action in the *Forty-Seven Ronin*, the most popular of all Japanese epics to this day, is the fact that the master of the Ronin was forced to commit ceremonial suicide because he had been wrongly instructed in court etiquette and was therefore laughed at during an audience with the Emperor. This fear of mockery can be endlessly documented from the literature and from the observations of every traveller to Japan from the most superficial to the most studious. The very unpleasant feeling of fearing mockery, of bashfulness, is called HAZUKASHII; and the fear of being mocked, and thereby "losing face" is a major motivator of Japanese behaviour.

I am not altogether settled in my own mind as to the mechanisms by which hostile laughter takes on so great a significance. It would appear that when a baby makes any lapse from the proper behaviour for its age—lapses from cleanliness, from politeness, mistakes in speaking—the onlookers laugh, half-embarrassed, half amused, and that subsequently the parents punish the child. In this way, hostile laughter would become a cue for subsequent punishment and withdrawal of love by the parents; and, although the punishments are subsequently forgotten in their concrete form, the fear of some vague and excessively terrifying punishment remains, for which the hostile laughter of others becomes the premonitory symptom. Theoretically this seems the most probable explanation; unfortunately, it is not nearly so well documented by my informants as the other aspects of Japanese childhood training.

With this I think the roster of the major themes of Japanese childhood training is complete; and I will now try to follow through the ramifications of some of these themes in adult life. I shall restrict myself to three themes: the learning associated with the control of the

gastro-intestinal tract, the learning associated with the attitude to parents, and the learning associated with the control of one's own body (including the expression of the emotions) and the social and inanimate environment.

The hunger of Japanese babies, as was pointed out, is, if anything, over-satisfied. "Hunger-anxiety"—an unrealistic fear that one may at some time in the future be completely without food—does not appear to be a component of the Japanese character, nor is it given ritual elaboration. The rites connected with agriculture, and the assuring of a good harvest, though of some importance, especially in the country, do not appear to have any strong emotional aura. Appetite, as opposed to hunger, would appear to be lowered by the occasional stuffing which children receive, and devices for tickling the palate have been very little developed in Japan. This is one of the most marked superficial contrasts with China; and although there are numerous Chinese restaurants for the wealthy and sophisticated in the cities, the arts of Chinese cooking have not been imported into the Japanese home. The emotional unimportance of food is also exemplified by the well-documented indifference of the Japanese to regularity of meals or of diet; far more easily than most Occidental peoples the Japanese, under the stress of competing drives, seem willing to postpone the satisfaction of hunger.

For adult Japanese the functions of food are somewhat disguised. For the leisured classes the æsthetic appeal to the eye, or the poetic associations of the name of the dish, are far more stressed than the appeal to the palate; and the ordinary people have given sexual connotations to the name of nearly every article of common diet. One might almost say that there was an aura of shame surrounding eating. It is noteworthy that in a culture which has ritualised almost every aspect of daily and ceremonial life, there is almost literally no Japanese table

etiquette; one eats at a separate table, and while eating can give vent to all those unseemly bodily noises which are otherwise unacceptable. There is no conversation at meals; one gets eating over as quickly as possible.

Besides the obvious implications of this attitude toward food, I should like to suggest that it is a derivative of the Japanese attitude toward cleanliness training; that the unpleasant effects surrounding defecation have moved forward to the eating of solid food, and that both aspects of the digestive process are treated almost identically.

A further derivative of this training is the excessive Japanese fear and dislike of dirt. Japanese cleanliness is so marked that every superficial account dwells on it, cleanliness both of the body and of one's possessions. Because of the psychological implications, it is worth noting that the excessive cleanliness of the Japanese is not absolutely complete. It is rigorously applied to the body, the visible surfaces of the Japanese house and garden, and to all public buildings built in Japanese style. Public buildings of Western style, on the other hand, and such "neutral" places as railway coaches and waiting-rooms, are likely to be far dirtier than their Occidental equivalents. Enemy country and captured towns are at best "neutral"; and consequently a Japanese conquering army is likely to be even dirtier and more destructive than their European counterpart.

These neutral areas, however, are relatively unimportant and cannot counteract the excessive fear of soiling and dirt. This fear would seem to be the fundamental psychological motive at the basis of religious Shinto ritual and belief. I quote from Sir George Sansom's *Japan: a Short Cultural History*.

"The outstanding feature of Shinto observances is the attention paid to ritual purity. Things which are offensive to the Gods were called . . . TSUMI . . . Chief among the offences to be avoided was uncleanness. It might arise in many ways, none of which necessarily involved

what, in other religions, would be moral guilt. Uncleanness of the person, from mere dirt, was scrupulously avoided, and it was a necessary preparation for religious observances to wash the body and put on fresh garments. Sexual intercourse, menstruation and child-birth were regarded as causing ceremonial impurity, which must be removed by lustration, abstention and prayer. . . . Diseases, wounds and death were also sources of uncleanness. . . . Sickness and all the external signs of disease, such as sores, eruptions and discharges . . . were also defilements. . . .

" . . . The list of offences does not reveal any distinction between ceremonial impurity and moral guilt. The consummation of a marriage is no less defiling than adulterous intercourse, a blow or a wound pollutes both parties to a conflict, and generally we find that the early religion is almost entirely deficient in abstract ideas of morality. Its code is not ethical, but customary and ceremonial. It reprobates as sins only such acts as are visibly or immediately repulsive. . . .

" . . . What is abhorrent, what must be washed away and expiated is not guilt but pollution. The concept of sin, as distinct from uncleanness, is wanting or rudimentary, and throughout their history the Japanese seem to have maintained in some measure this incapacity to discern, or this reluctance to grapple with, the problem of Evil."

Outlined in this quotation are the ethics peculiar to the Japanese—"The concept of sin, as distinct from uncleanness, is wanting." This too I would derive from the drastic toilet training. In all human societies, the innate drives of new-born infants have to be controlled in ways acceptable to the adults of the society, and this control is mostly taught very early, and chiefly by punishment. Two of the chief drives which must be controlled are sex and excretion. Where infantile sexuality is prohibited, it is prohibited absolutely; there are no places and no occasions when a child is allowed to strive for whatever sexual pleasure is physiologically possible for him. Where this prohibition is enforced

rigorously, there would appear always to be moral absolutes in the value system of the society: absolute prohibitions, absolute sins, a concept of absolute evil, a constant contrast between the unreachable ideal (of purity in the first place) and actual mundane practice. Excretion, on the other hand, cannot, for physiological reasons, be absolutely forbidden; all that can be forbidden is excretion at the wrong time or in the wrong place. If this cleanliness training lies at the bottom of the value system of the society, it would follow that there would be no absolutes, no "right" or "wrong," but instead very strong emphasis on doing the right thing at the right time, on the minute following of ritual, on physical and ceremonial cleanliness, on "correct" or "suitable" behaviour, which would be defined by the context in which the behaviour took place. This would seem to fit the case of Japan.

Since there is so much emphasis on behaviour suitable to a given situation, the drive to adapt to any new situation is very strong, since the sanctions for non-adaptation are among the most terrifying the average Japanese experiences. Consequently, although the Japanese are bound by a conservative ritualism in the Japanese environment, they are likely to be as adaptive as they can in any foreign situation. Also the sanctions for correct behaviour and the standards of correct behaviour which are operative in a Japanese environment would be no longer operative in a different environment and under different circumstances; and consequently all the aggression and cruelty which is unsuitable in Japanese contexts can be allowed vent.

In the last few remarks there is implicit yet a further derivative from the early toilet training; that is the emphasis on neatness and tidiness, on there being "a place for everything and everything in its place" (which might be considered the motto of toilet training). The Japanese carry this emphasis extremely far; their interior decoration and landscape gardening are constantly

admired examples of this minute preoccupation with correctly placed detail; not a leaf or a piece of paper may be out of place. This perfectionism reaches perhaps its highest point in the highly ritualised Tea Ceremony, where every detail is clean, controlled, and free from intrusion. Similar manifestations are the minutely regulated rituals, most highly elaborated around the Court, but present at every social level and in every sphere of activity; if the ritual is completely and carefully copied, then there is no fear of "doing the wrong thing in the wrong place."

In contemporary psychology an individual preoccupied with ritual, with tidiness and order, is technically known as a "compulsive neurotic"; these characters with us are statistically unusual, and it is consequently justifiable to speak of them as neurotics. The Japanese character traits which I have just described, however, are statistically common, and therefore it would be unjustifiable to speak of the Japanese character as neurotic, unless one were appealing to some unformulated and universal ideal of the "normal"; the Japanese do, however, show most of the traits which in individuals would be called compulsive. In European compulsive neurotics, excessively severe early cleanliness training plays an important, indeed preponderating, rôle in the development of their symptoms.

Behind the rituals of the individual obsessive can always be discovered a deeply hidden, unconscious and extremely strong desire to be aggressive; the rituals are a psychological protection against the putting into effect of this dangerous urge. The reasons for this are neither spooky nor abstruse. Such early thorough training, before the baby has learned to speak, or can possibly understand the reasons for it, indeed before the appropriate muscles are really strong enough, can be produced only through severe and continuous punishment and by painful effort on the part of the child. The child automatically resents these pains imposed upon him and

would like to destroy the author of them. But the child is too weak to gratify these desires; and later it learns that the source of these pains is also the source of all its pleasures and gratifications; the desire to destroy the source of all its pleasures, even though it inflicts pain, presents such a menacing picture that even the desire must be hidden, unnamed. Unfortunately, it can never be destroyed.

Japanese society normally gives almost less opportunity than any other of which we have record, for the socially approved release of vicarious aggression; and, on theoretical grounds, one would therefore expect that this aggression is ready to be released in excessive quantities under suitable circumstances. This theoretical construct gives the best explanation for the striking contrast between the all-pervasive gentleness of Japanese life in Japan, which has charmed nearly every visitor, and the overwhelming brutality and sadism of the Japanese at war, which has horrified almost every observer and journalist and shocked the conscience of the democratic world.

With this I think we have carried the theme of the learning associated with the gastro-intestinal tract far enough (many may think too far); I should now like to pursue for a little the theme connected with the learning associated with the attitude towards the parents. This theme applies almost exclusively to male Japanese.

It will be remembered that the Japanese boy has to be continuously subservient and deferential towards his father and elder brothers, but may be aggressive and commanding toward his mother and sisters. Because of this differential treatment received from and allowed toward his two parents, the Japanese boy grows up in a divided universe where he must continuously use careful discrimination. To the male part of the universe—that is all males of superior age and status—he must respond obediently, passively and unquestioningly, following the example that they lay down and taking orders they give;

only by so doing will he be safe and rewarded; any other action invites drastic punishment. Complementary, as he grows older, he will learn that younger men and men of lower status will give him the unquestioning obedience that he gives others. The male universe is an ordered pattern in which reward is gained by compliance and a full knowledge of relative status. From the Emperor (with his divine ancestors as his superiors) to the newborn infant (with the outcasts as his inferiors) every male has his exact place in this male world; upward aggression will be punished directly by those affected, excessive downward aggression by mockery from those above. The male universe gives assurance and safety, but little indulgence; it administers the heavy punishments for deviation, controls the sanctions and all the secondary rewards. One must comply with the patterns of the male universe. Resistance and aggression are dangerous.

In contrast with this male world of dominance and submission, there is the female world from which come all the primary gratifications (food, drink, warmth, sex) and which can be controlled and forced to yield up its gratifications by aggression or threats of aggression. The male world gives orders and expects obedience; the female world threatens and pleads, but can always be made to yield if the male is sufficiently strong and persistent in his aggressions. The female world is loved, ill-treated, and despised.

This division of the world of the male Japanese into two contrasting aspects is fully developed in Japanese symbolism and philosophy. Female is "dark" and "passive," male "light" and "active"; the land is male, the sea female, the sun male, the moon female, and so on. But this dichotomy has still further implications. The growing child sees the universe in terms of its parents; and this original division is never fully dissipated by later experience. It seems certain that to the contemporary Japanese other races and societies are

viewed as either male or female : as groups to be followed and obeyed implicitly, or as groups to be forced to yield to aggression or threats of aggression. Further, it appears historically as though in the nineteenth century England and America were viewed as indubitably male, and therefore to be obeyed and copied as much as possible ; but that, in the last forty years, the sex of these groups has been first questioned, and then reversed. The defeat of the Russians in 1905 probably originally called in question the "virility" of the whites ; and this uncertainty was increased by the willingness of the Anglo-Saxon to negotiate, to bicker and yield, instead of commanding, in the next twenty years. Finally, in the invasion of Manchuria, and subsequently, the Japanese found that the Anglo-Saxons showed all the female characteristics ; they cajoled and threatened without carrying out their threats ; they constantly yielded to a show of aggression, each time vowing that that concession would be the last ; they parleyed ; they allowed their nationals to be ill-treated or insulted without retaliation ; they were feminine and would therefore yield the primary gratifications ("raw materials") if enough aggression were used. On December 7, 1941, this theory was put to the test ; and the democracies still held their feminine rôle. Most convincing of all, they asked for mercy, declaring Manila an open city ; and just as on such a plea the angry boy will destroy his mother's hair-do and break her precious pins, so in response did the Japanese destroy Manila with special attention to buildings of religious or symbolic importance.

Our final theme was the learning associated with the control of one's own body and the social and inanimate environment. It will be remembered that the chief social learning the young Japanese underwent was learning correct social behaviour, how to sit properly and how to bow, and learning what parts of the house were safe and what were not. Furthermore, there was an aura of fear and anxiety about learning to sit and bow

properly, for criticism or mockery by strangers would bring punishment from the parents.

From the moment a Japanese child can understand language—one might even without much exaggeration say from birth—standards of etiquette, of correct and suitable behaviour under varying circumstances are demanded from him. As soon as the child leaves home these standards of correct behaviour and adequate accomplishment are demanded to "honour the family name," so that "the family name shall not be disgraced." Recognition of this motive is given somewhat ludicrous expression in some of the arrangements of Japanese schools ; every child is moved up in grade every year, and all the athletic events are so arranged that every pupil gets a prize. If one failed to do so, not only would the child itself feel unhappy, its whole family would feel disgraced.

This point of the individual representing a larger group is stressed from early childhood ; the size of the group represented tends to increase as the individual grows in status ; it is not uncommon for Japanese in foreign parts to feel and say that they represent the whole nation. The fear of criticism from strangers is one of the chief motivating forces for young Japanese during the whole of their childhood and adolescence ; it is the most potent threat for enforcing conformity. While they are able to avoid such adverse criticism, the Japanese are given complete support and approval by their own group, especially the extended family ; but if the individual arouses criticism in strangers, or if he fails to measure up to the demands made on a person of his age and sex (e.g., failing to get a rise in grade in a "modern style" school) then his own group will turn on him, punish him severely, even repudiate him, if the criticism is strong enough. It is this situation which is probably at the back of the fact that most Japanese soldiers prefer to die rather than be taken prisoner ; a prisoner is considered weak and womanly, a person in

whom no man should have any interest; to be taken prisoner means complete repudiation, means no group and no position to go back to after peace is declared. It is such a dismal alternative which makes death seem preferable, not a non-existent tradition of suicide. In peace-time the suicide rate of Japan was less than a third that of parts of Germany.

It is perhaps worth emphasising that the degree to which this repudiation by one's own group is carried is very rare sociologically. In most societies where the extended family or other fractional social group is operative, the group will usually rally to protect one of its members who is under criticism or attack from members of other groups. Provided that the approval of one's own group is maintained, one can face the rest of the world with the assurance of full support in case of need or attack. In Japan, however, it appears the reverse is the case; one is only sure of support from one's own group as long as approval is given by other groups; if outsiders disapprove or criticise, one's own group will turn against one and act as the punishing agents, until or unless the individual can force the other group to withdraw its criticism. By this mechanism the approval of the "outside world" takes on an importance probably unparalleled in any other society. The implications of this theme for the understanding of Japanese foreign policy appear so obvious that it is unnecessary to expatiate on them.

This approval from strangers is one of the ways in which the Japanese try to mould the environment to their satisfaction; but approval of free groups is always uncertain; people may withdraw their approval. Owing to the methods by which, and the society in which, the Japanese are brought up, no Japanese can feel safe and secure unless the whole environment is understood and as far as possible controlled. The uncontrolled and unknown are dangerous and frightening; from the small child who risks severe punishment if he does not know

where the house-joists are, to the nobleman who risks shame and embarrassment if he does not know the exact rank, age and family of a new acquaintance, the unknown and uncontrolled are always equated with the danger of mockery from others and punishment by one's own group.

This desire for a controlled universe is manifested in a very great variety of ways; in the decoration of the houses and gardens, in which every detail is controlled and in its proper place; in the complaints so frequently made by foreigners that the Japanese open a friendly interview by enquiring the name, age, business, family position, etc., of the person they are addressing; in the meticulous observation, the note-taking, the photography, which are such persistent features of the Japanese abroad; in the minute copying, and thereby controlling, of foreign articles; and (as a converse of this attitude) in the extreme unwillingness of the Japanese to admit that they do not properly understand and control a foreign language, which has been the cause of endless imbroglios.

Besides these domestic features, Japanese history—especially the history of Japanese legislation—shows this constant urge to control the environment as completely as possible. Two consistent and only apparently contradictory trends can be seen running through the whole of Japanese history: these are the attempt to legislate against all change, so that the whole social environment is controlled; and, secondly, the unformulated belief that some non-Japanese society has a less oppressive solution for social regulation, and an attempt to impose that scheme or solution on the whole of Japanese society through minute legislation. Of the former trend, the most striking example was the policy of exclusion for two centuries preceding the Meiji restoration; of the latter, the whole-hearted adoption of the forms of Tang civilisation in the eighth, and Sung in the twelfth century; and the adoption of Western technology and ideas since

1867. This adoption has been extremely thorough and legislated; it is even reported that debates were held in the Diet as to whether April Fool's Day should be included in the Japanese ceremonial calendar. The consistent theme in both trends is the attempt to control by imposed authority whatever is strange and unknown in the environment.

During the period of exclusion, everything outside Japan was specifically recognised as dangerous, because unknown; so much so that a Japanese leaving the country was not allowed to return for fear that he should bring unknown and dangerous ways back with him. It may be an echo of this period—certainly an echo of this trend—that the most usual Japanese greeting—O-KAWARI-GOZAIMAZEN-KA—literally means "I trust there has been no change (since we last met)." Change implies unpleasant change.

With the reversal of policy since 1867 the danger of the uncontrolled outside world has not diminished; but now the Japanese are attempting to cope with the danger by dominance, instead of by withdrawal. It is a recognised principle of psychology that an organism faced with a frightening object will respond with either withdrawal or attack; after two centuries of the former method the Japanese have now tried eighty years of the latter. Their almost continuous history of aggressive warfare (Korea, China, Russia, the Triple Alliance, China, the United Nations) can, it would seem, be profitably viewed as recurrent attempts to control the dangers of an unknown and ever-expanding environment. Each portion of the environment subjected and controlled, however, leads on to ever more unknown and dangerous neighbours. This largely unconscious fear of the environment is insatiable. The Japanese can never feel safe unless, as some of their more bombastic military speakers have proposed, the Mikado rules the whole earth.

I have tried to develop three themes of Japanese culture from their impact on the young child to their

remote effect on all of us in this country, indeed in the whole world. The selection of these three themes has inevitably been arbitrary, and it would have been possible to develop a number of others. The themes are those which seemed to me to be of most obvious relevance; and they have, I hope, served as a demonstration of a relatively novel methodology and approach to complex and relevant problems.

DANGER! DIRT!

ONE of the worst places for catching an illness used to be in hospital. Of course, wherever a crowd of people occurs, whether in bus, cinema or air-raid shelter, infection is bound to spread more easily from one crowd member to another; and in hospital where most of the members of the group already have their own diseases, it is quite easy for them to transfer them to one another. It is for this reason that doctors are not keen on admitting very young children to hospital, especially to the so-called isolation fever wards. They tend to run so easily through the whole range of illnesses available—scarlet fever, mumps, dysentery, and so on, one after another.

Recently, it has become possible to demonstrate this very prettily. Bacteriologists have discovered that the germs of some diseases may be classified into various individual families or groups by means of various delicate precipitin tests. Thus it is known that the hæmolytic streptococcus is the cause of scarlet fever, and this germ can be grown in a characteristic way on blood agar medium in a dish from the throat of any person with the illness; under the microscope the germs from different cases look alike, stain the same way with different dyes, and generally, are indistinguishable. But the precipitin test shows that the germs from one case may belong to a different family from those of another, and there are commonly five or six different families to choose from. This knowledge enables us to track down the source of infection. Suppose Johnny K. has scarlet fever and Group A streptococci are found in his throat; then shortly after, Brian Smith goes down with the same illness. If Brian is found to have Group B germs in his throat it's no use Mrs. Smith going round and shouting at Mrs. K., because Johnny cannot have infected Brian. Group A germs do not give rise to

anything but Group A; Brian's Group B must have come from someone else.

In the same way, when scarlet fever seems to be clearing up, and then comes on again, it can now be shown that the return of the illness is actually due to a new germ picked up while in hospital—one of the same kind but a different family.

The war has stimulated an interest in infected war wounds, and it is now apparent that most of the infections are actually picked up by the wounded man *after* his arrival in hospital. Some of the infection was

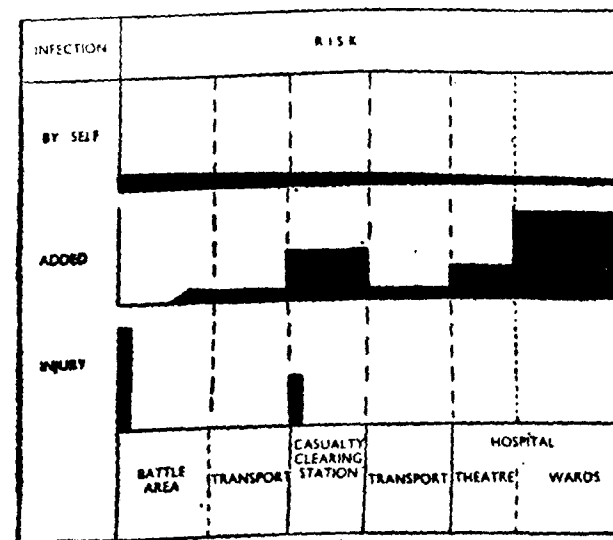


FIG. 4

The risk a front-line casualty runs of getting his wounds infected; the most dangerous time is in the ward of the base hospital. (Re-drawn from Miles.)

carried directly from one patient to another by the nurses dressing the wounds. This has now been stopped by arranging the dressings as team work, ideally by three people, though two will do. The first person does

nothing but remove the old dirty dressings, the second nothing but applying the sterile clean ones, while the third hands round the instruments without touching them directly. In this way dirty and clean never come in contact, and so the spread of germs is minimised.

CLEANING THE AIR

Some of the wound infections come straight up off the hospital floor. It is obvious, except to conservative housewives, that dusting is a most inefficient way of cleaning: it just pushes the dust around, off the mantelpiece on to the chairs, or from the windowsill to the table. Hospitals realise this and have special vacuum cleaners to suck the dust away into a bag, but even then some dust is shot into the air and takes as much as half an hour or so to settle again. So it has become the rule that all sweeping and dusting in the surgical ward must be over thirty minutes before dressings begin, and the floors and the blankets on the beds are oiled to gum the dust down and prevent it blowing in every breath of air.

This is no protection if people go around sneezing and coughing without using a handkerchief, and so emitting a yard-long blast of germ particles, free to float in the air for a considerable time. Disinfecting the air is thus a particularly important problem under the conditions of modern life, and one not yet well solved.

The London Underground uses a certain amount of ozone in the air passing into the stations, but it is doubtful whether this is very effective. The discovery that germs did not like sunlight led to further investigation in which it was shown that the ultra-violet part of the radiation is the most germicidal. With the development of low-pressure mercury vapour lamps rich in ultra-violet light and cheap to operate, it became possible to try them out in hospitals. The lamps are fixed seven or eight feet up near the ceiling, with a reflector to prevent any direct light falling on people's eyes, since this is extremely unpleasant. Doctors Wells, Wells and Wilder tried the

method in a school in Philadelphia over a period of four years, and recently reported that children who worked in classrooms fitted with the germicidal lamps had much less illness, particularly measles and chicken-pox, than those in the ordinary rooms. Experiments in a hospital ward, with mice in pens instead of patients in bed, showed that very few mice were infected by pneumonia germs purposely shot into the air, provided the lamps were on, but that if they were off, most of the mice died.

One of the drawbacks to these lamps is that they are a nuisance and expense to fit. Recently, however, the possibility of chemical disinfection of the air has at last come nearer to practicability. Most poisonous gases, such as chlorine, for example, kill man before they hurt the germs, and fluids like phenol are good for drains but ineffective in the atmosphere. But there has now come forward propylene glycol, a close relative of ethylene glycol, the anti-freeze of cars and planes, which is cheap, easy to spray into the air, harmless to human life even in high concentrations, and promises to be extremely effective against aerial germs. The problem of cleaning the air seems now well on the way to full solution. When the new methods can be put into general use, there should be not only a decrease in the more severe infections, but also in 'flu: and we may, at long last, be able to do something for the common cold—at least in the way of prevention.

SELF-STERILISING SURFACES

It is an old joke now, the story of the young American researcher who got his Ph.D. degree by writing a thesis on "Washing-Up." He did at least draw attention to the fact that washing the dishes does not do more than remove the visible dirt: the plates and cups and cutlery will still have all the germs they had before. For ordinary household purposes, perhaps this does not matter very much, but public drinking cups, and restaurant spoons, and hospital equipment, would be much

improved if they kept themselves bacteria-free and so unable to pass on germs from one person to another.

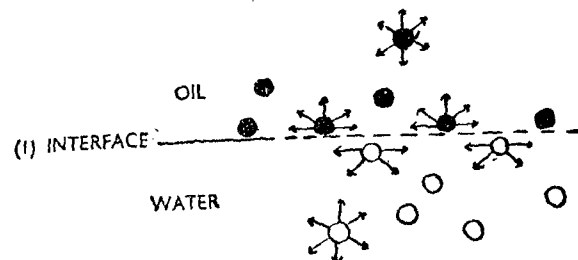
Very recently, substances of this type have been produced for the first time. Any bacteria in contact with them are rapidly killed, but they are quite safe to touch with any part of the human body. Their action depends on the fact that traces of some comparatively rare metals, such as silver, are extremely poisonous to bacteria, much less so to man. In order to prepare large quantities of self-sterilising surface, the silver is incorporated into a plastic; the metal at the surface of this is not dissolved rapidly by water, but it can escape into the proteins of the bacteria and kill them. It is also, of course, picked up in minute and harmless quantities, by the proteins of the skin which touches the surface; and this gradual loss of silver has to be made good by diffusion of new silver from the underlying layers. The main difficulty to be overcome was to find a plastic which would hold the silver in a form which did not allow it to be washed away in water, and yet allowed the slight loss through protein contacts to be replaced by diffusion. But this has now been done, and the silver-plastic can be produced as a paint-like fluid, ready to be sprayed on to the article to be treated.

ABOLITION OF SOAP ?

Oil and water do not mix. Most dirt has a film of grease over it, and it is this which makes washing the curse of small boys and the problem that it is. Recently the chemists have been very busy on two points: finding out why oil and water do not mix, and on the other hand, why soap helps them to—at least to the stage of getting a fine emulsion of oil in water, or “milk.” The answer to the first problem has been found to lie in the fact that all liquids seem to have a kind of skin or film at their surface which holds the fluid together and discourages its molecules, in incessant motion, from wandering away into the atmosphere or the pores of the bowl in which it

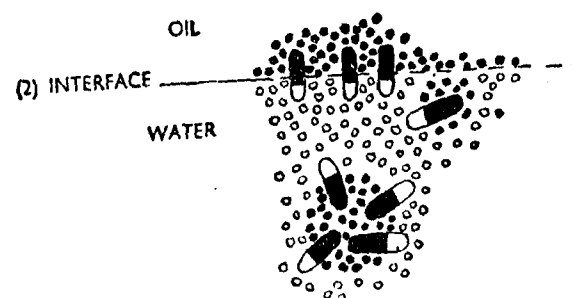
DANGER ! DIRT !

is kept. It is this skin in the case of water which allows the parlour trick of the floating needle. The strength



- (1) Dark circles represent oil molecules, light circles water molecules. The arrows on some of them show the directions in which they are attracted by each other. Below, the shape of a soap molecule (diagram).

WATER SOLUBLE → ← FAT SOLUBLE



- (2) When soap molecules are present, some lie across the interface in both oil and water phases, and draw groups of oil molecules into the water.

FIG. 5

the skins of various liquids varies—in the case of oil and water both the skins are very strong and prevent mixing. The second problem, the secret of soap, has been

solved much more recently. Soap can be made by treating mutton fat with caustic soda, and it turns out that the real effect of this is to make molecules like short flexible rods, a long fatty piece with a short acidic non-fatty piece at one end. Now a pure fatty piece dissolves in fats but not in water; suet mixes with olive oil but not with gravy. And on the other hand, a pure acidic or salty piece dissolves in water but not in olive oil (e.g. table salt). So a soap molecule in water with oil about is rushing up and down, one end of it trying to dissolve in the oil and the other to stay in the water. The result is that soap accumulates at the oil/water skin surface, the molecules breaking up the skin altogether by having one end in oil, the other in the water, and trying to bring the two together. In other words, soap enables water to wet grease, and so fetch the dirt off.

This discovery, that a long molecule fat-soluble at one end, water-soluble at the other, is the secret, led to many experiments in the joining of the different kinds of fatty- and water-soluble pieces, with the result that chemists have found many suitable substances, some much better than soap. Some of these are now being sold in tooth-pastes, or for washing clothes—the dirt just streams off when they are dissolved in the water. One in particular, cetyl trimethyl ammonium bromide (or CTAB for short), is now much used in hospitals for cleaning dirty wounds and for cleaning the skin prior to surgical operations. It is antiseptic in the sense that it is able to wash most of the germs away.

Apart from their cleaning properties, these new soap-improvements are useful to agriculture. So many moulds and insects have a waxy covering, that a water spray is quite ineffective: it just does not wet them. But a detergent added to the spray does, and this is the reason gardeners prefer soapy water for spraying their rose-trees to get rid of greenfly. In industry also they are useful in oil-wells and in mining: crude ore can be frothed up and a separation obtained between the light

pieces held in the froth and wanted, and the heavy useless stuff which sinks to the bottom. Even in cooking they may prove their use, because successful frying is possible only if the frying fat "wets" the food, which usually contains a fair amount of water.

D.D.T. SPELLS DEATH

Bugs and lice and flies of one sort and another have always been associated with dirt and the spread of disease, and scientists have for years been studying the problem of their elimination. The battle is not won yet by any means, but the development of D.D.T. (dichloro-diphenyl-trichloroethane) during the war, and its magnificent success at Naples, has been a great victory. It will be remembered that a typhus epidemic broke out there in mid-winter, 1944, but was stopped in three weeks. This was made possible because in that time no less than 1,300,000 civilians were dusted with D.D.T. powder at the rate of 73,000 a day. The powder spelt death to their body lice, which are responsible for the spread of the disease in its epidemic form. For there are two forms of typhus: the endemic, or common all-the-year-round form, which is caught from rats, or rather rats' fleas which actually carry the typhus germ; and the epidemic form which bursts out suddenly when the germ is caught by head and body lice from the typhus-infected man they live on, and transferred by them in their wanderings to other, healthy people. D.D.T. eliminates body lice and stops the epidemic disease, but until all rats can be persuaded to attend centres for treatment, the endemic form will persist and act as a reservoir of infection from which fresh epidemics can burst out. Typhus is primarily a disease of the rat flea, just as malaria is in the first place a disease of the mosquito; and man catches these diseases secondarily from the insects they afflict.

Curiously enough, D.D.T. has been known to chemistry since 1873, when the German, Othmar

Zeidler, first made it. But its value as an insecticide began to be appreciated only when Paul Muller, of the

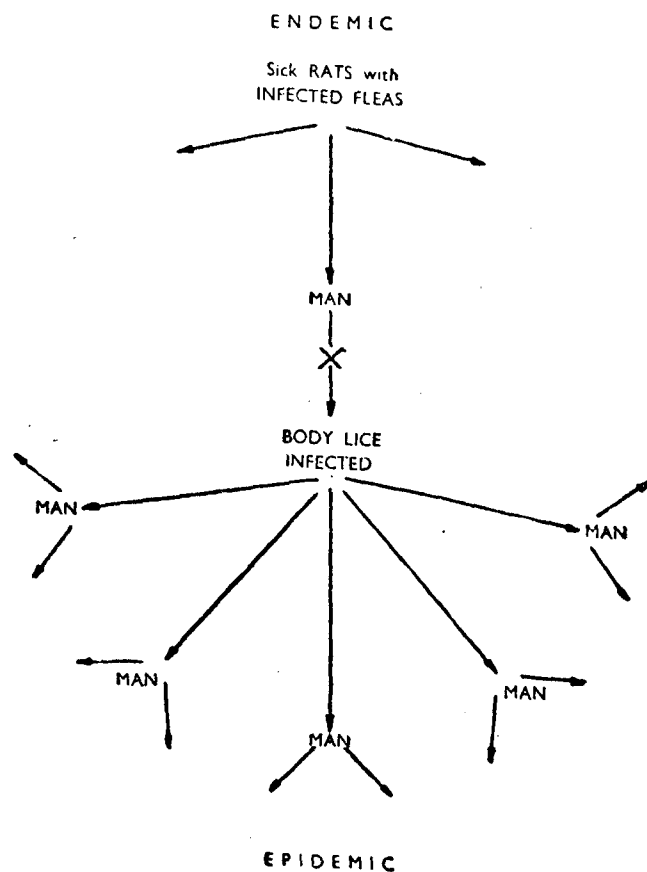


FIG. 6

The spread of typhus. D.D.T. acts at X and prevents spread by body lice.

Geigy Chemical Company in Switzerland, found in 1939, that it would kill potato beetles. Before that time

two good insecticides were already available, substances extracted from plants growing in the tropics. One, pyrethrum, obtained from a species of chrysanthemum grown in Japan and to a certain extent in Kenya, has the advantage of a quick "knock-down," which is to say that it quickly lays the insects low, but has to be continually re-applied as it has poor persistence, and in addition it is irritating to human skin. The other, rotenone, extracted from Malayan derris root, and one or two other members of the bean family, has a slow knock-down but is a persistent dust, unfortunately, however, with a smell of its own. In addition, it is poisonous to man.

The development of the Far East war cut off the sources of most of these insecticides, but fortunately research had already been under way for some time, in particular to develop anti-louse substances. British troops wore belts impregnated with certain organic thiocyanates next the skin, and each new belt kept them louse-free for a month—but unfortunately, when the men sweated, their skin absorbed the insecticide and became sore. The Russians were using diphenylamine, and a stuff called bis-ethyl xanthogen with some effect. But all insecticide research has to be very much hit-or-miss guess-work. There are no rules: it is just a matter of trying possible substances to see if they work, and D.D.T. was one such lucky guess, probably the luckiest yet.

D.D.T. is simply made from coal tar benzene, chlorine, alcohol, and sulphuric acid, in very large quantities. The U.S. alone made it at the rate of 300,000 lb. per

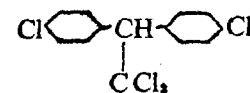


FIG. 7

How the atoms are arranged in a molecule of D.D.T.

month during 1944 and expects the 1945 monthly output to be nearly two million pounds. It is a white, practically odourless stuff, very persistent, but with only a slow "knock-down." It will stand prolonged boiling in water, and light shining on it. It has no effect on human skin in the amounts in which it is used, though a large dose by mouth is poisonous; but with insects the story is quite different. Even a trace of D.D.T. present in a surface on which an insect is walking will penetrate through the hard waxy "skin" or cuticle of the insect wherever it touches. Once inside the insect's body the poison goes straight to the nerves, which are paralysed, so that the insect undergoes, first arrest, and then death.

People are still exploring its possibilities but some of them are now well known. Incorporated in oil-bound water paint for house decoration, or sprayed directly on the wall, it keeps the room clear of flies for two to three months, for every fly that lands, dies. Beds sprayed with 10 per cent D.D.T. in kerosene keep clear of bugs for over three months, clothing dusted with it stays free of fleas and lice for six or eight weeks, and can be laundered six or eight times before the protection is lost. A few ounces of D.D.T. dropped in a malarial swamp kills all mosquito larvæ; it is death to cockroaches, moths and various, but not all, veterinary and agricultural pests—aphids and codling moths, for instance. But there is one catch: it cannot distinguish good insects from bad, and bees, for instance, are also killed. There is also always the possibility that by killing off one sort of insect you merely encourage one of its less successful but more unmanageable competitors to become a pest. You drive out the black rat, as it were, and so make room for the brown. When all is said and done, however, D.D.T. is undoubtedly a great advance. But there still remains much investigation of insect killers to be done and further substances to be developed; and scientists are working at this minute on the job.

METALS

SIR LAWRENCE BRAGG

(1) WHAT METALS MEAN TO US

WE employ various materials to build or fabricate the many objects we use in everyday life, choosing those whose properties are most suitable for the purpose which the object has to serve. Certain of these materials have been used from the earliest times, such as stone, wood, leather, and animal or vegetable fibres, each with its own peculiar valuable properties. Stone resists crushing and is very durable and permanent, as indeed it must be, since it has so long resisted change as a part of the earth's crust. It is therefore ideal for walls and buildings, and very early in his history man discovered how to make artificial stones by burning clay, with the advantage that they could be given any desired shape, and made into bricks or given elaborate forms as pottery. Wood is strong and tough and light, it resists tension as well as compression, and is not brittle like stone. It forms beams and furniture and parts of tools or weapons. Leather is tough but at the same time it is flexible; it is ideal as straps or sheets. Vegetable fibres such as linen or cotton, and animal fibres such as wool and silk, owe their value to their flexibility and strength in resisting extension. They can be spun into yarn or rope, and woven into cloth. The technological age in which we are now living is replacing the natural products used by early man by a series of artificial products, but it is remarkable to see how in nearly every case we are copying Nature's materials. The wide use of concrete represents a developed art of making artificial stone. Artificial fibres, such as rayon or nylon, replace cotton, wool, and flax. Plastics are coming very much to the fore; they correspond to early man's use of horn, another

substance with peculiar properties of toughness in all directions without the "grain" of wood. For the most part we are following in the footsteps of our remote ancestors, though we can make for ourselves what they had to cull from wood and field. There are exceptions; for instance, we have discovered comparatively recently the number of uses to which natural rubber can be put, and are now making it artificially. This is a really new discovery; our ancestors had nothing with such remarkable powers of elastic stretching without breaking, and resistance to being abraded.

Metals represent one vast range of materials, however, which have no natural counterpart. They have to be won from the earth, where they exist in a cunningly hidden form. Mankind only slowly realised their potentialities. They were at first rare and precious, used for very special purposes. Great store was set by them, and trade routes sprang up for their commerce. It must have been by chance that some early Tubal-cain discovered that when certain stones were heated in the fire, a substance with hitherto undreamed-of properties could be beaten out, and so became, as Genesis relates, "an instructor of every artificer in brass and iron." Modern civilisation is based upon the use of metals to an extent which is always increasing at a truly extraordinary rate. Sir Thomas Holland, in reviewing our resources, states that far more metal has been taken from the earth by men since 1900 than in the whole of the previous history of mankind.

What gives metals this distinctive character we all recognise as "metallic," which makes them play a unique part in our material civilisation?

Their most striking mechanical attribute is that they are hard and strong in resisting compression and extension, and that at the same time they are tough and can be distorted without breaking. They can be dented or hammered or drawn into wire, and so far from being weakened by maltreatment of this kind, they become

even stronger than before. A stone is hard and strong, but once it yields it breaks completely; it is brittle. What new possibilities were opened up to primitive man when, instead of flint, he first came to know of a material for weapons and tools which was as hard as stone and yet could be relied on not to snap! Again, metals can be moulded to our purposes by heat. Familiarity dulls the keen edge of appreciation, but most of us can probably remember the thrill of seeing a blacksmith make a horseshoe, converting the strong iron into something as soft and pliable as clay by heating it red-hot. The final properties of steel depend on the history of its heat-treatment. A steel spring, if heated and cooled slowly, is relatively soft and can be bent into any desired shape, cut, or drilled. If it is heated and suddenly cooled or "quenched" it becomes very brittle. Warm it up again to a relatively low temperature, and it becomes "springy." Or take the kind of iron from which files are made, containing a high proportion of carbon. If cooled slowly it is so soft that the teeth of the file can be cut on it. Heat it, and quench it by plunging it into brine, and it becomes glass-hard and fit for its work. It is such properties which make metals the ideal materials for the vast complex of machinery on which we now depend.

Metals are essential to us in another way now that we have made electricity our servant. They conduct electricity, and iron (along with some other elements) can be magnetised. A cable is laid across the Atlantic; in other words a few strands of copper wire are surrounded by a thin sheath of rubber composition and deposited on the sea floor. What a remarkable thing it is that if an electric current is fed into the cable in England, it prefers to travel along the wire to America rather than jump the intervening inch or so of insulator which is all that prevents it taking a short cut back home through the sea! I think it was Oliver Wendell Holmes who, on seeing a tram drawing its energy from a tenuous

overhead wire, said it was power stripped stark naked. The possibility of sending messages and power by a metallic conductor has had incalculable social consequences. It has linked the world into an organic whole by providing it with a system of nerves by which the consequences of what happens in one part of the globe are immediately felt in other parts. Biologists rank living things in a scale of ascending complexity of their nervous systems; we are living in a world which has possibilities of much higher organised life than that of our forefathers, and we are trying to adjust ourselves to the new conditions, with shattering consequences. The use of metals has brought about the change. The recent war was fought with weapons of metal made by metal machines; the possession of sources of metal determines its strategy; the whole world has been involved in it because of the metallic links which bind it together. One may say that the vastly increased use of metal has determined the character of the war, and to a large extent has been responsible for the social changes which have brought it upon us.

(2) THE METALLIC STATE

The science of chemistry is concerned with the compounds which are formed when the various elements are combined together. The atomic theory had its origin in an attempt by Dalton to explain the proportions in which the elements combine. More recently, physicists have studied the structure of the atom and have gained a greater understanding of the forces which bind atoms together. It would take us too far to plunge into the theory of atomic structure in this article, but certain aspects of it may be recalled which indicate the fundamental nature of the metallic state.

The many different kinds of atom, some ninety-odd in all, may be roughly divided into two great classes, electro-positive and electro-negative. The periodic table displays the elements ranged in ascending order of

atomic complexity, and in it the inert gases which have no chemical affinities stand out as neutral landmarks at important points in the table. The atoms which occur after them in the table are markedly electro-positive, those which come just before are equally markedly electro-negative, and the character changes as one passes from one inert gas to the next in the series. Interpreted in terms of atomic structure, the electro-positive atoms are those which easily part with one or more of the negative electrons surrounding the nucleus of the atoms, and thus change from neutral atoms into positively charged ions. The electro-negative atoms easily absorb one or more additional electrons into their structures, changing from neutral to negative in charge. These two classes are the Bulls and Bears of the atomic Stock Exchange; the one has electrons it is prepared to sell, the other lacks electrons and is willing to buy. The majority of elements are electro-positive; they are the metallic elements.

To continue our broad generalisation, which we will not confuse by the qualifications which would have to find a place in a more detailed account, there are three main types of compound, or association of atoms. They are illustrated in a pictorial way in Fig. 8.

The most simple is an association of electro-positive and electro-negative atoms. Common salt, NaCl , is an example. The electro-positive atoms of the metal sodium part with their electrons to the electro-negative atoms of chlorine. The resulting positive sodium ions and negative chlorine ions are held together by electrostatic attraction, as in Fig. 8 (a), in a kind of chessboard pattern. Such a structure is typical of inorganic salts in general, although the negative unit is often a complex of several atoms.

Quite a different type of association is characteristic of organic compounds. Two or more electro-negative atoms, both short of electrons, fuse their structures into an intimate combination. This tightly knitted whole,

like that of naphthalene illustrated in Fig. 8 (b), is what the chemists term a "molecule." Such a molecule can go through physical adventures, such as melting, vaporising, or being dissolved in a solvent, while still remaining an entity. The electro-negative elements carbon, oxygen, and nitrogen have the strongest powers of forming such groups, and with a ballast of hydrogen they form the basis of the vast complex of compounds studied by the organic chemist.

In fibres, such molecules are incorporated in long chains by linking each to the next. In horn, and in some plastics, they are joined by side-links as well.

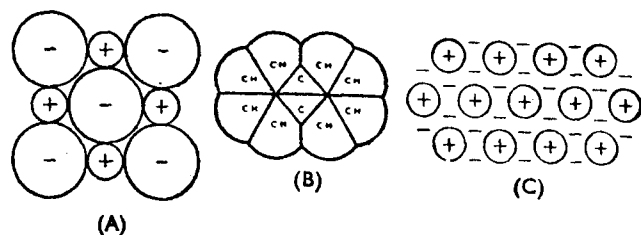


FIG. 8
Types of atomic association.

Long chains with links free to rotate, so that they can wriggle, and joined only by infrequent side-bands, form a material with the properties of rubber. It can be seen that this power of linking on any number of atoms to the structure leads to an infinite variety of molecular forms. Nature has seized upon this possibility in order to construct the vast molecules of which living bodies are built, containing thousands of atoms, where the complexity is necessary to enable them to perform such varied functions.

The above may be called the plus-minus and minus-minus chemical compounds; there remains a third class, the plus-plus, shown in Fig. 8 (c). It is composed of atoms all of which lose electrons easily. We may think of it as an array of positive ions, with a system of elec-

trons held in common between them all. It is quite a different type of compound from those illustrated by (a) and (b). The relative numbers of atoms in (a) are fixed by the alternation of plus and minus, and in (b) by their association into definite family parties or molecules. In (c) it is possible to replace one kind of electro-positive atom by another, as long as the new-comer is not too incompatible in size and other properties with its neighbours. When the atoms are all of one kind we call the structure a pure metal; when they are mixed we call it an alloy, and it is natural to find that the electro-positive or metal atoms can be alloyed together in a wide range of proportions. The general cloud of electrons can drift through the structure, endowing the metal with its power of conducting electricity.

(3) A MODEL WHICH ILLUSTRATES THE METALLIC STRUCTURE

We have seen that the metallic state has certain peculiar features. In a sense metals are not true solids. There are no direct bonds between atom and atom binding the whole together. The positive ions actually repel each other, and are only held in a compact mass by the attraction of the negatively charged common system of electrons. This structure indicates the explanation of the most characteristic feature of a metal, the way in which it can be hammered or dented or rolled without breaking down its continuity. However the atoms slither over each other, the continuous electron cloud remains to hold all together. A metal is more like a crystallised liquid than a solid.

An immediate reaction to such a picture of a metal is the question why a metal has any strength at all if the atoms can slide over and past each other so easily. The answer is very interesting. If a pure metal is cooled from the molten state under controlled conditions so that the atoms are built into a single perfect crystal, it has practically no strength at all.

It is a queer experience to handle such a crystal in

the form of a long rod. It is as weak as a similar rod of plasticine and can be stretched at first by the fingers with hardly any resistance. Directly it is distorted by stretching, however, it becomes stronger, and finally when it is thoroughly maltreated it assumes the strong rigid character we associate with metal in the ordinary state. A simple experiment with a copper wire illustrates this feature well. If the wire is supported horizontally by one end and a Bunsen flame played along it, the wire becomes very soft. It does not become a single crystal, but it "anneals" into a conglomeration of highly perfect crystals which show the effect. In this state, a very small weight hung on its end bends it over. Bend it back to the horizontal position, and it will support the weight. Bend it backwards and forwards a few times, and it becomes very stiff. "Cold work" has made it strong.

A two-dimensional model of the metal structure can easily be made which illustrates these properties in rather a fascinating and suggestive way. Our model must have numerous "atoms" of exactly equal size; these atoms must be round, they must slither over each other without any friction, and there must be some general force of attraction holding the whole together. Plate 6 shows a raft of tiny bubbles floating on the surface of a soap solution, which will do just what we want. The little bubbles all stick together by capillary forces, like the "sixpence" in one's teacup when it is stirred. By blowing them through a small orifice under the surface with a constant pressure equal to about 20 cm. head of water, a remarkable constancy of size can be achieved. The perfection of the rows in the "crystal" of Plate 6 is evidence of the regularity. The bubbles are about 1mm. in diameter.

A raft roughly rectangular in outline can be attached to supports on either side, and we can try the experiment of shearing it. Springs just lying on the surface of the solution make convenient supports because, by adjusting

the tension, one can make the pitch of the spring fit a row of bubbles on either side. If now one spring is slowly moved tangentially, the raft at first strains elastically. After a certain amount of sheer strain, however, one can see a few bubbles on one of the free edges becoming unstable and slithering over each other, and then suddenly a movement runs along a row from one edge to the other across the raft, like a ladder in a stocking. The bubbles in turn "move on one," and when this movement has gone right across, the top and bottom of the raft become displaced by one bubble width relatively to each other. This can be repeated several times. Plate 3 shows typical rafts—(a) before and (b) after a succession of these movements of slip. When a single metal crystal is extended, as Professor Andrade has found, it does so by slipping along crystal planes; in our two-dimensional model we have "slip-rows" which behave in a similar way.

The graph in Fig. 9 shows how this phenomenon may be studied quantitatively. The ends of one of the springs are attached to a pair of long thin vertical glass fibres which are held rigidly at their far ends. A telemicroscope with a scale in its eyepiece is focused on one of these glass fibres, so that we can measure the force on this spring by watching the displacement of the fibre. The other spring is moved parallel to itself by a micrometer head. It is thus possible to establish a stress-strain curve as shown in Fig. 9, where the strain or relative movement is plotted horizontally and the stress measured by the bending of the glass fibre is plotted vertically. The upper graph runs from left to right. The raft is at first elastic as shown by the upward slope of the graph, until the point is reached where slip takes place, when the stress falls back to zero or even a little past the zero. As we continue to shear, it builds up again till further slip takes place. At the end of the upper graph the shearing movement was reversed, and the graph repeated in an inverted form.

In the next paragraph I wish to indicate the significance of this effect as regards the strength of a metal, but before leaving our model I would like to draw attention to some other suggestive features. In a single perfect crystal the atoms are arranged in absolutely regular rows and sheets. When, however, there are a number of crystals in the metal which are variously orientated with respect to each other, the atoms at the boundaries must somehow adjust themselves so as to make the best of both worlds. Plate 4 shows a raft composed of four such "crystals," and it is

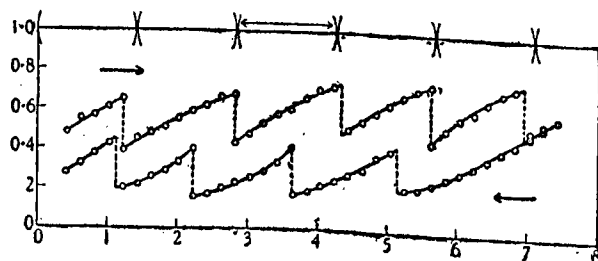


FIG. 9

A stress-strain curve for the sheared raft. It yields each time the shearing movement increases by one bubble width.

interesting to see the way the boundary is marked out by a series of dislocations or misfits. The structure of each crystal can be seen right up to the boundary, but it is slightly distorted by the necessary adjustment of the atomic positions at the boundaries. We can see that a simple slip process is confined to one crystal only; it cannot continue into the next, when a fresh start must be made. Plate 5 illustrates another feature which is exceedingly important in metallic structure. A few bubbles of different size have been deliberately introduced to represent atoms of impurity in the metal. They spoil the regular structure in a remarkable way, upsetting the rows for a considerable distance. We see here an explanation of the very large influence of

small amounts of impurity on the mechanical and other properties of a metal. Each atom of impurity affects a large volume all round it because it throws the regular rows out of their stride.

Another feature well shown by the model is the power of the metallic structure to recover from distortion. It has an indestructible crystallizing power; it cannot stay in an amorphous or irregular condition. The raft can be crushed by moving one spring towards the other. Slips take place along rows in directions making 120° with each other, but the bubbles always adjust themselves so that the raft remains crystalline. By moving the springs slowly apart again, we can "draw out" the raft, and again the bubbles slip and move so that new rows appear between the spring and we are left with a regular crystal as before.

(4) THE STRENGTH OF A METAL

A single perfect crystal of a metal is extremely weak, gliding along its slip planes with hardly any resistance. If, however, it is cold-worked, the perfection of the structure is destroyed. Different parts are orientated differently, and many dislocations like those illustrated by Plate 4 must be created. At the same time it becomes stronger, so the strength must in some way be dependent upon the distortion of the structure. We can use the analogy of the model to show how this comes about, and even to calculate in a rough way an estimate of its strength which is in approximate accord with that measured experimentally.

Fig. 10 shows typical measurements of stress and strain made with a test piece of polycrystalline pure iron by Smith and Wood. As the tension is applied to the specimen, at first it yields elastically as shown by the lower curve, and if the tension is released it recovers its original length. Beyond a certain point, about 8 tons to the square inch in this case, it yields. It is pulled out by the tension, and does not recover if the tension

is released. The yield is very large compared with the elastic extension, so the strains for the upper curve showing the yield are plotted on a scale reduced a hundredfold. In yielding, it is distorted and hardens, so being enabled to withstand the greater strain, until finally at about 18 tons to the square inch it breaks. The yield-point, as we have seen, is greatly influenced

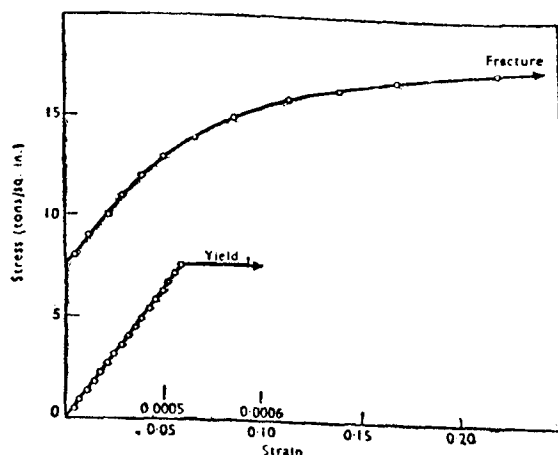


FIG. 10

The stress-strain curve for pure iron (S. D. Smith and W. A. Wood, Proc. Roy. Soc., May, 1941).

by the previous history of the metal. Yield occurs at a low stress if the metal is well annealed and at a high stress if it has previously been cold-worked. The coefficient of elasticity, which defines the ratio of stress to strain, is, on the other hand, almost independent of the state of the metal, and is only slightly affected by impurities. In other words, all samples of iron follow at first the same curve in Fig. 10 within their elastic range, but may break away from it at very different points. This distinction is important. To define stress and strain, we may picture a cube of the material of unit

dimensions on each edge. The shear stress is the tangential force on opposite faces tending to slant it over, the shear strain is the angle it is slanted through in consequence. The coefficient of elasticity is the ratio of stress to strain.

A possible clue to the factors which determine the point at which a metal ceases to stretch elastically, and begins to yield, is afforded by Fig. 9. The little raft of bubbles shears elastically until its top edge has moved

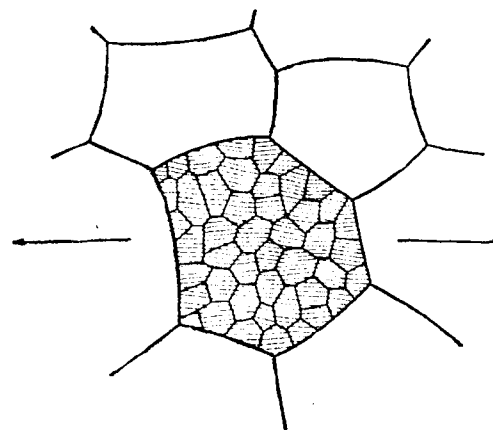


FIG. 11

A diagrammatic representation of the fragmentation of a metal crystal by cold work. (*Nature*, 1942, 149, 511.)

on by about one bubble width as compared with the bottom edge; the stress is then released by a slip of one row of bubbles over the other. It must obviously wait until it is sheared about this amount before it is worth while slipping, so to speak, because if it slipped when it had only moved on a fraction of a bubble width it would end up with a greater strain in the opposite direction. If s is the width of a bubble and t the breadth of the raft, the shear strain builds up to an amount about s/t before slip takes place.

Now picture our metal as built up of a number of differently orientated units as in Fig. 11 of average size t . Each bit must slip independently, and the smallest jump which can take place is the distance s between nearest atoms, like the bubble width in Fig. 9. We should therefore expect that the metal could be strained up to an amount s/t elastically, but that beyond that point it would yield. Corresponding to the strain s/t , there will be a yield stress ns/t where n is the appropriate elastic coefficient. The distance s between neighbouring atoms is given by crystal analysis of the structure, and the elastic coefficient for shear is a well-known constant for any metal. If, therefore, we can get an estimate of t , the dimension which limits the extent of an individual slip process, we can calculate the yield stress and compare it with what is observed. The measurement of t should of course be made on the specimen whose yield we are going to measure, because, once it yields, t gets smaller and the yield-point goes up.

We can make a shot at the elusive t by means of a well-known optical principle. A highly perfect optical grating with a large number of regularly ruled lines produces very narrow or "sharp" spectra when monochromatic light is diffracted by it. If the number of lines in the grating is reduced, the spectra become broad and diffuse, and there is a simple relationship between the number of lines and the breadth of the spectra. A corresponding phenomenon is observed with X-rays. The X-ray diffraction lines produced by a well-annealed specimen of pure metal are sharp, but when the same metal is cold-worked the X-ray lines become broad and fuzzy, owing to the breakdown of the perfect crystals and the creation of dislocations and strains. There is a limit to the amount the lines can be broadened in this way. The metal has a high power of recrystallisation, and if momentarily excessively shattered it heals its wounds to a certain extent. Wood has estimated the lower limit of fragment size in several pure metals by

ascribing the whole of the line-broadening to size effect, and in the following table these breadths are used to calculate their yield stresses in shear :

	s (cm.)	t (cm.)	ns/t (tons/in. ²)
COPPER	2.56×10^{-8}	0.7×10^{-5}	10.6
NICKEL	2.49×10^{-8}	1.2×10^{-5}	10.3
SILVER	2.88×10^{-8}	0.8×10^{-5}	6.7
IRON ¹	2.42×10^{-8}	3.2×10^{-5}	4.1

¹ This figure is for pure iron, which is a very weak metal as compared with the carbon-containing iron to which we are accustomed.

It is interesting to see that these calculations give figures of about the right amount. When one goes into the matter more closely, however, many complications appear which show that we are touching only the fringe of the problem. Different X-ray diffraction lines in a given specimen do not broaden to the same extent, as if, to put it loosely, the perfection had a different range along and across the grain. The form of the distortions in the metal is unknown, for it will be seen from the above table that they are on far too small a scale to be measured under the microscope. There is the serious objection to the above calculation, that the broadening is probably largely due to local strains in the metal caused by the cold work. Such strains cause variations in the scale of the crystal pattern from point to point, and so also make the diffracted beams diffuse. Nevertheless, it is interesting to note that if we assume that, by estimating the range of perfection by the breadth of the X-ray lines, we are also estimating the dimensions of the individual slips, we do get figures which are at any rate of the right magnitude.

We can now see in a qualitative way why a metal is strong, and how its strength can be increased. It is strong if each little slip process is confined to a short run in the metal and not allowed to spread over large perfect crystal grains. This restriction can be brought

about by cold work and by putting foreign atoms in the metal to spoil its perfection of structure. Plate 5 illustrates the effect of atoms of impurity which distort the regular rows.

One might now ask, why not spoil the structure so much as to inhibit slip altogether, and so make it exceedingly strong? Here we come up against a curious paradox, which is really at the root of the valuable mechanical properties of the metallic state. In order to be strong, a metal must be weak. A body which cannot slip is brittle. When it is pulled, there is bound to be somewhere a minute crack or point of weakness, as was first pointed out by Griffiths, and at the sharp end of this crack there is an excessive strain which causes the crack to deepen; in other words, the material tears across. Brittle substances can be strong in compression because cracks do not then extend, but they will not stand being pulled. In a metal, on the other hand, just because it yields when it is pulled too hard, a crack will not deepen. The metal gives way at this point and relieves the strain. A very simple experiment which anyone can try illustrates this effect. The "Cellophane" used for wrappings is brittle when dry, slightly plastic when moist. By gumming cardboard supports to the top and bottom of a strip of "Cellophane," leaving the edges free as in Plate 7, so that cracks do not start from them, one can hang on it a very considerable weight. If it is pricked with a needle-point when dry it breaks instantly. If now one breathes on the "Cellophane," the needle-prick has no effect. The "Cellophane" flows enough around the pricked point to stop the spreading of a crack. I am obliged to Dr. Orowan for this illustration.¹

Here is another one of a more homely character. A smile is ordinarily quite a pleasant movement, but we all know how painful it can be when the strain is con-

¹ Note that for this experiment to succeed when the air is moist the "Cellophane" sheet must first be artificially dried.

centrated at one point owing to the rigidity associated with a cracked lip.

(5) SUMMARY

At the beginning of this article, the peculiar metallic attribute which makes metals an essential basis for tools, machines and structures was defined as a combination of strength and rigidity with toughness. We can now see how this peculiar combination of opposed qualities is brought about. The metal parts of a machine may give elastically, but they must not yield in the sense of becoming permanently deformed by the strains ordinarily placed upon them. Yet they must always hold this power of yielding in reserve, so to speak, if the metal is to retain its other precious property of reliability. As Griffiths has shown, thin fibres of glass or silica can be as strong as steel if they are fresh and have no cracks, but a touch on their surfaces makes them snap instantly under a strain. Though glass is harder than steel we cannot build our machines of it, for any sudden jar would smash them to pieces. A metal is reliable because it knows when to yield, and in yielding becomes even stronger. The art of compounding and heat-treating a metal to fit it for various mechanical tasks is a matter of nice compromise. We harden it by forging and hammering and mixing a metal with other metals, or putting carbon in iron, and go just as far as we dare while still preserving its ultimate power of yielding slightly under excessive strain. The peculiar atomic structure of a metal, the way the atoms can move past each other without breaking bonds, the way in which their relative positions can be altered by heat-treatment in the solid state, these are the qualities which make it so ideal a material for technology. We have only begun to explore the possibilities of creating new alloys with still more desirable properties. In the past great advances have been made in the metallurgical art by trying out various new combinations and discarding those which

showed no improvement. The more we can pry into the fundamental factors, which determine strength, the better the prospect of advancing more directly towards our goal and achieving even more spectacular successes in this age of metals.

BIOLOGICAL FRONT

OTHER EYES THAN OURS

Is the world *really* just what we think it looks like? Or is it only our eyes which make it seem like that? Philosophers have debated such questions for centuries. But we can now investigate the behaviour of an animal which must in fact see the world somewhat differently.

As most people know, the white light of the sun can be split up by a prism into a spectrum of colours. A normal man can distinguish about 150 different hues in it, ranging from red through yellow, green and blue to violet; beyond the violet lies the ultra-violet, which tans our skins but which we cannot see. Now you can find out what colours a bee sees; you offer the bee a chequer-board of different colours, with a little honey on a square of a particular colour, and if the bee can distinguish that colour, she becomes trained always to go to that colour first. It turns out that bees do not distinguish nearly as many hues as we do. Red, orange, yellow and green all look alike to them; they are one colour, "bee-yellow." A different colour is "bee-green," which we see as a bluish-green. A bee can also see a "bee-blue" which includes the blues and violets. But the really odd thing is that it sees another colour which we don't, in the ultra-violet.

Of course, there is no way of telling what this colour looks like; but we can perhaps get a slight hint. To our eyes, certain colours are "complementary"; that is to say, if you mix them you get a sort of grey. Thus red is complementary to green, and yellow to violet. Now bee-yellow is complementary to bee-blue, as one might expect. And the ultra-violet colour is complementary to bee-green.

This system of vision would produce a pretty queer-

looking world. Red and yellow flowers would look the same in hue (though probably not in shade) as the green leaves. Some things which look black to us, but which reflect some ultra-violet light, would look coloured "ultra-violet" to bees. On the other hand, things would look white only if they reflected all the bee-visible light; and we know that some of our white flowers do not reflect ultra-violet, and so would look bee-green to the bees.

The world does not, indeed, look the same to the bees' eyes as it does to ours. So what is the world *really* like? The answer, surely, is that by looking at the world with our eyes we have been able to describe its colours in terms of wavelengths of light, and we find that this same description is adequate to describe what the bee sees. So what our eyes have told us about the world is not wrong; it is merely not complete; and the same is true of what the bee learns about its world. The "real" world is both of them, man-world and bee-world together.

THE FÜHRER IN THE FARMYARD

Biologists are not only teaching us something about the senses of animals these days, they are telling us also something about the way animals live together. This subject, under the title of "Natural History," has of course been studied for some centuries, but nowadays the approach is different. Biologists no longer seek to explain what they see in terms of human feelings, and their observations are often more precise. Their results in the field of animal sociology may well prove important for the development of the human social sciences.

A flock of hens who are used to living together, for instance, is not just a haphazard collection of individuals, but a community in which each bird knows its place. It is organised on the basis of something very like the Nazi "leadership principle." Each hen has her place in a pecking order: she has what Professor Allee of Chicago calls a "peck-right" to attack her inferiors with

impunity, while her superiors have the peck-right over her. In some flocks there is only a single order, A over B, B over C, C over D, and so on. But sometimes there are complications; P may have the right over Q, Q over R, but R have it over P, while the whole group of P, Q and R, is below O and above S. Again, in many birds, though not so much in fowls, the peck-right depends on where the birds are; a low-ranking bird may go up in the pecking order when it is on its own home territory.

The pecking-führer is not necessarily the leader in all the activities of the group. When a flock of hens is turned out to forage, there is usually no very definite leader, different birds coming to the front at different times. As Allee remarks: "As far as true leadership is concerned, the foremost bird is only following along ahead of the flock. A somewhat similar relationship between leader and followers has been observed among other animals, notably with ants and with men."

Low-ranking hens get so chivvied about by their more aggressive sisters that their egg-laying performance is reduced; it is often a good plan to split up a large flock into two groups in which the differences in aggressiveness are not too marked. Cocks kept together away from hens also develop a pecking order. This has no relation to the sexual aggressiveness of the different cocks when each one is introduced singly into a pen of hens. But when a whole group of cocks is allowed to run with the hens, the cocks with high peck-rights tend to chase the low-ranking cocks away from the hens and prevent them mating. The interesting fact emerged that when a low-ranking cock had once been thoroughly shooed off a group of hens he failed to act aggressively towards them even when the superior cocks had been removed; he had learnt his lesson, and so had the hens, who repelled what few advances the cock did make. So a bird's aggressiveness depends partly at any rate on its previous experience. Allee showed that the same is true of mice, which develop a fighting order much like the hen's

pecking order. And mice behave according to the very human principle that nothing pays like success; if a mouse is matched off against a series of poor fighters, so that it enjoys an unbroken run of successes, it is found to have gone up in fighting grade and to be aggressive towards individuals it had previously submitted to.

It is very probable that aggressiveness, like some other characteristics, depends on the amounts of certain chemical substances or hormones circulating in the blood. Of course, one of the difficulties in comparing aggressiveness with amount of hormone in the blood is the technical one of getting a good method of estimating the hormone. Meanwhile, the biologist studies external factors, light, for instance. Dr. Bissonnette, in America, has shown that light has a stimulating effect on the sexual life of birds, and indeed, of many other animals. He was in this way able to explain one of the long-standing puzzles of biology—why most animals breed only in the spring. He showed that it was an automatic response to the lengthening days. As a check on the theory, when he was in England he examined some starlings from London, which had artificial light at night as well as normal daylight. He found that they came into breeding condition earlier in the spring than country starlings, which had no artificial light: not inappropriate for the birds under the lights of Piccadilly in the good old days. As to how the light affects a physiological process in the starling, it seems that nerve messages pass from the eyes through the brain to a little gland underneath, the pituitary, which then produces a hormone to do the trick.

THE SEXUAL RHYTHM

The sexual rhythm is not, however, purely a matter of light (though attempts have been made to link the monthly period in women with the recurrence of the full moon!). Most female mammals come into "heat" at regular intervals; and in man and his near relations,

the higher apes, the rhythm of mating periods is transferred into a rhythm of uterine bleeding. *Until recently the standard theory was that the sexual rhythm is caused directly by the growth and liberation of egg-cells one after another in the ovaries. It has been conclusively shown that as an egg grows, the cells surrounding it*

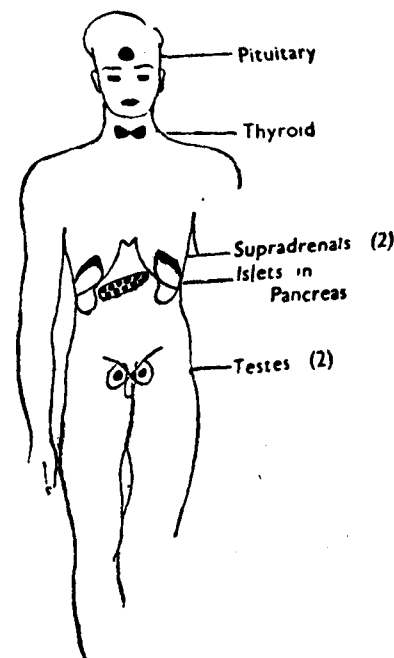


FIG. 12

form a particular hormone which diffuses into the blood and causes the changes characteristic of the first part of the sexual period; and similarly, after the egg has become fully grown and been shed from the ovary, another hormone is produced which controls the changes of the second half.

Recent work seems to show that this is not the whole

of the story. Biologists at Oxford first removed the ovaries completely from female rats, and then gave them just sufficient of one of the sex hormones to keep them going. Surprisingly enough, the rats showed typical sexual rhythms. The periodicity must have been due to something other than the ovaries. One's first guess at the organ responsible would probably be the pituitary gland again. It is well known that the numerous hormones that circulate in the blood work together like the members of a team; but the hormones made in the pituitary very often seem to be the most important ones, and a prominent expert has called the gland "the conductor of the hormone orchestra." But in this case it is not the pituitary which is responsible for the rhythms in the ovary-less rats; rhythms still occurred in rats without ovaries or pituitaries. As far as the Oxford workers could determine, the glands responsible are the little adrenals, which lie near the kidneys; but the evidence is still not quite convincing and the investigations are going on. The important thing is that a new stage is beginning to open out in our understanding of the sexual processes of animals—and quite apart from any discoveries of (human) medical importance which may be made by future developments of this line, infertility of the female is still a source of enormous loss every year to the stock-farmer.

One field where hormone research really is beginning to help the farmer is in milk production. In order to produce milk it is normally necessary to allow the animals (cows or goats) to mate and bear young; and unless these young are killed immediately for meat, they require some of the milk their mother gives. A recent biological discovery may make it possible to get adequate supplies of milk without mating the animals and waiting for them to have unnecessary offspring. Milk secretion, like the sexual rhythm, is controlled by hormones in the blood. For instance, strong doses of the female sex hormone oestrin stop the flow of milk: and this has already been

used in some cases to assist in bringing lactation to an end when a baby is weaned. Smaller doses of oestrin may merely cause a change in the composition of the milk (actually enriching it). Finally, in some animals, it has been possible to induce the secretion of milk from virgins which have never borne young by implanting a tablet of an extract of the pituitary gland or of some synthetic substances, under the skin. The underlying mechanism is not fully understood yet, however. The presence of one hormone in the blood undoubtedly affects the rate at which the other hormones are produced, and thus alters the whole hormone balance of the organism. Until we find out exactly how the hormone balance is shifted by any given dose, and how the various possible balances affect functions, like milk secretion, the artificial control of milk secretion will remain the rather chancy, hit-or-miss affair it is at present. But it ought not to take us long to get to the bottom of the matter.*

BIGGER BIG TREES

The biggest living things are the giant redwood trees (*Sequoia*) of California, which have about ten times the bulk of the largest whales. Size is controlled by the hereditary factors which lie in the chromosomes inside the nuclei of the cells which make up the animal or plant. A drug known as colchicine (it is made from the yellow autumn crocus, *Colchicum*) upsets the growth of the cells in such a way that the number of chromosomes, and thus of hereditary factors, is doubled; and for some reason not fully understood, plants with double the normal number of chromosomes are usually giants. *Sequoia* seeds treated with colchicine have already grown leaves and twigs thicker than normal, and there is not much doubt that when they grow to full stature they will be taller than the normal redwoods.

* Recently, Folley and his collaborators at the National Institute for Research in Dairying, at Reading, have shown that hexoestrol given by mouth will start lactation in the virgin cow.

THE VITAMIN DETECTOR

Talking of changing the hereditary factors in the chromosomes of cells, we should mention that a good way of doing this is by shining X-rays on them. Although we cannot make any change we want, if the reproductive cells of the organism (e.g. in the testicles of an animal) are subjected to fairly large doses of X-rays, a large number of changes will occur in the hereditary factors carried in them—and the chances are that some of the changes will give the sort of hereditary character we are looking for. This fact has enabled the invention of the "Vitamin Detector" to be made. This is not a device you can keep beside the teapot on the breakfast table to see whether your cereal actually contains all the vitamins the makers claim. It is in fact a laboratory technique which makes it not only possible to do a fairly rapid and sensitive estimation of the amount of some particular vitamin in any food, but also provides a way of exploring for new vitamins not yet detected. It is, moreover, a very pretty example of the kind of biological tool which scientists are just beginning to learn how to handle; it is as much a manufactured research instrument as is a microscope or a balance, but it is built, not of metal and glass, but of living protoplasm.

Its working is based on recent advances in the study of heredity. It has been known for some time that there are hereditary "diseases" or abnormalities which consist in the failure of the body to carry out some chemical process which the ordinary body can perform. For instance, the "Spotted Dog" (or Dalmatian coach-hound, to give it its official title) differs from most kinds of dog by having lost the power to break down uric acid into a harmless stuff called allantoin. So it is the only kind of dog liable to gout! Again, normal rabbits can break down the yellow colouring matter of plants (xanthophyll) into colourless compounds, but there is a hereditary factor which deprives the animals of the power to do this, so that the yellow pigment is deposited

unchanged in their fat, giving an appearance which many people strongly dislike, though there is really no harm in it.

The theory of the Vitamin Detector, then, is to take some organism which can normally manufacture all its own vitamins for itself; to X-ray it, and thus to produce races which lack the power to manufacture some one vitamin or other. Such a race will not be able to grow on a synthetic medium until it is supplied with the vitamin which it cannot make: and the more vitamin it is given, the better it will grow. We, therefore, shall have an easy way of detecting the presence of the vitamin, and even of measuring the concentration of it. All we have to do is to try out the detector-race, see if it will grow on the food in question, and if so, how fast.

But manufacturing the detector-races is not so easy. There are two more snags—luckily they can both be got over at once. The first is that not so many organisms can normally make all their own vitamins. Men have to get theirs from somewhere else—hence the importance of adequate supplies in the diet. Even most plants are dependent for their first stocks of vitamins on the stores laid down in the seed. But some of the lower plants, such as moulds and fungi, can live permanently off the very simplest chemical substances, making all their own vitamins as they go along. So a mould or a fungus is the choice for a detector.

And some of them make it possible to circumvent the second snag. Most animals and plants possess two of each kind of hereditary factor, one from the egg cell and one from the sperm cell. If, say, the male parent has been X-rayed and has, therefore, produced many sperms containing abnormal hereditary factors, in his offspring the action of these factors may be complicated or even obscured altogether by the factors derived from the non-irradiated female parent. If both parents are irradiated, the situation is not much better, because it is very unlikely that two germ-cells, changed in exactly similar

ways, will come together in any of the offspring. In fungi, however, the cells of the individual contain only one of each factor, not two. The whole thing is like the germ cell of a higher plant or animal; the stage when the cells contain two of each factor, instead of being most of life, lasts only for a very short time. In the fungus which has been chosen as a detector, the "body" is a shapeless mass of thin threads, each of which is a chain of cells. The sexual process consists of two of these threads fusing to give a cell with two of each kind of factor. But these fertilised cells almost immediately divide three times to give a row of eight spores, each of which again contains only one factor of each kind. From these spores new fungi can grow; and if a hereditary factor has changed so that it cannot make a particular vitamin, the spore produces a fungus which will grow on foods containing that vitamin and not on foods which do not.

And that is the whole set-up of the Vitamin Detector, as it has been developed at Stanford University, California. The particular fungus chosen, the name of which is *Neurospora*, has been X-rayed, and from the progeny cultures have been selected, each of which lacks the power to manufacture one particular vitamin. Its rate of growth on any food can be determined very quickly, and is an accurate measure of even minute traces of the vitamin in question, perhaps too minute to be detected by chemical methods.

Moreover, *Neurospora* can be used to discover new vitamins in this way. The normal fungus can grow on a solution containing very simple salts and sugars, since from these it can make all the substances it needs. But if the progeny of X-rayed fungi are tested on these simple solutions some fail to grow. Most of the failures are due to inability to make some known vitamin, and one has only to go on trying all the vitamin preparations in the laboratory till one has found the right one. But in some cases none of the pure vitamins will do the trick, although the culture may be able to grow on some

general nutrient such as beef tea. Then one knows that there must be something in beef tea, which has not yet been extracted in pure form, but which is essential for growth—that is where the chemists get busy, trying to identify it. Of course, in the first place these substances can be assumed to be essential only for *Neurospora*. One might think that animals would need something quite different. But actually, the essential substances seem to be much the same for all living things. It is known that many of the recognised human vitamins are just as necessary for the growth of plants. Similarly, there are some amino-acids (the building blocks out of which flesh proteins are made) which man cannot make for himself but has to get ready-made in his food; they are not usually called vitamins, but there is no real reason why they shouldn't be. X-rayed races of *Neurospora* turn up which lack the power to make just these amino-acids out of all the many kinds which are known: it is clear that they are particularly crucial amino-acids, for *Neurospora* as for man.

The Vitamin-Detector is quite new. So far, several races have been produced which lack the power to make some substance which is not one of the vitamins or other essential substances already known. But up to date no one has yet been able to make a definite identification of any of these new discoveries. We must wait a little longer, till the chemists have extracted and purified them.

WHY VITAMINS ANYWAY?

You will have noticed that most of the "protective foods" which contain vitamins are vegetables. We get Vitamin A in green vegetables; Vitamin B (there are really several different Vitamins B) comes from seeds, such as whole wheat; Vitamin C is found in fruits, such as oranges, and in new potatoes and parsley. Only Vitamin D is not primarily a plant product; we either make it in our own bodies if there is sufficient sunlight, or we get it, along with Vitamin A, at second-hand in fish-liver oils.

continuous but is made up of particles, called atoms. There are ninety-two different varieties of atoms corresponding to the ninety-two known elements of nature. Sometimes these elements are able to exist as free atoms under normal conditions, as is probably the case in liquid mercury. More often, however, they are found united with others to form a group of atoms, called a molecule. In simple cases the molecule may contain only two atoms of the same kind, as is the case for the gases oxygen, hydrogen and nitrogen. More often the molecule may be made up of atoms of different elements, and the substance is then called a chemical compound. Any given compound, then, is built up from numerous identical bricks, called molecules, the molecule containing a definite number of atoms bound together by chemical forces in a characteristic pattern. The atoms are infinitesimal in size according to our usual standards, being about one hundred millionth of an inch in diameter. The molecules may range in size from those containing only two atoms to those containing many thousands of atoms.

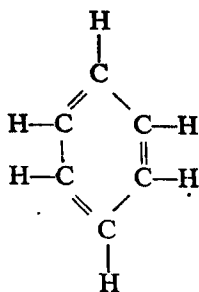
To understand why atoms unite to form molecules, we must look into the structure of atoms. Rutherford showed that the atom can be regarded as a miniature solar system. In the centre is the nucleus, a positively charged particle containing most of the mass of the atom. Around it revolve the electrons in their orbits, just sufficient in number to balance the positive charge on the nucleus and make the atom electrically neutral. The electron is the ultimate particle of negative electricity, and possesses a negligible mass. These orbital electrons are of supreme interest to the chemist, as they determine the chemical properties of the atom. Each element is characterised by a certain number of orbital electrons, ranging from hydrogen (1 electron) to uranium (92 electrons). Only a certain number of these orbital electrons are chemically active, usually from one to seven. These "chemical electrons" are characterised by their tendency to pair off with similar electrons in other atoms

and to form a chemical bond. Such a bond (called a covalent bond) arises between two atoms when one electron from each unites to form an electron-pair. There is a further type of bond, called an ionic bond. This arises when one electron passes from one atom to a second atom. The first atom then becomes positively charged and the second negatively charged, and the two charged atoms (called ions) are drawn together by ordinary electrical attraction to form a molecule.

The first attempts to analyse the motion of an electron in its atomic orbit naturally used the mechanics developed by Newton for the ordinary objects of everyday life, such as apples, cannon-balls and stars. These attempts were unsuccessful, and it was subsequently found that only by using a special form of mechanics, called wave-mechanics, could the motion of an electron be analysed. Further, wave-mechanics shows that the electron has a tendency to form chemical bonds of the two types just mentioned. We shall later indicate the way this theory has clarified our ideas about reaction rates, but firstly we must discuss the concept of "valency."

In any discussion of chemical compounds we must first distinguish them clearly from physical mixtures. The latter may usually be separated by a sufficiently ingenious physical method (which in a simple case may devolve into separating two distinct kinds of crystal by the use of a pair of tweezers). Chemical compounds are formed by the binding together of atoms of different elements by specifically chemical forces, to give molecules. These forces possess the characteristic property of saturation. This is because they arise from the orbital electrons mentioned above, which link up in a pair of electrons from each atom, to give the chemical bond. An atom of hydrogen can never bind more than one other atom. If this other atom be another hydrogen atom, then we have the simple molecule which makes up hydrogen gas (written as $H-H$, or H_2), or if it be a chlorine atom we have the compound molecule hydrogen

chloride ($\text{H}-\text{Cl}$, or HCl). The *valency* of hydrogen is said to be one. Similarly, since an oxygen atom can bind two hydrogen atoms, in water (H_2O) its valency is said to be two. The valency of carbon is four; it may bind four hydrogen atoms in methane (CH_4), or two oxygens in carbon dioxide ($\text{O}=\text{C}=\text{O}$, or CO_2). In the last example we see that we may have more than one bond between two atoms. A reasonably complicated molecule is that of benzene, C_6H_6 , which may be described (though not completely) by the formulation



This is an example of a ring compound. It arises largely from the distillation of coal, and is the basis of the synthetic dye industry.

The chemical forces, that is those within the molecule which hold the constituent atoms together, are much greater than the so-called forces of cohesion between the molecules themselves. Using the usual units of the chemist, the energy of a chemical bond is about 70,000 calories per mole. Benzene, containing twenty-four such bonds, will therefore possess an energy of about 168,000 cals., and this is the energy that would be required to separate the molecule into its constituent atoms, on this simple picture. On the other hand, we require merely about 8,000 calories to boil liquid benzene, in which process we separate the individual molecules from each other, transforming the liquid into a gas.

Each chemical compound, then is made up of mole-



PLATE 1. Cuttings of white pine rooted by treatment with auxin. The cuttings are in groups of four. Top left: untreated, no roots.

Top right: low concentration of auxin, three rooted. Lower left: Medium concentration, all rooted. Lower right: High concentration, all rooted.



PLATE 2. Heads of oats at maturity; variety, "Victory." Above, grown from untreated seeds; below, from seeds treated with auxin for the first 24 hours.

Illustrating
GROWTH
HORMONES
IN PLANTS
(pp. 9-17)

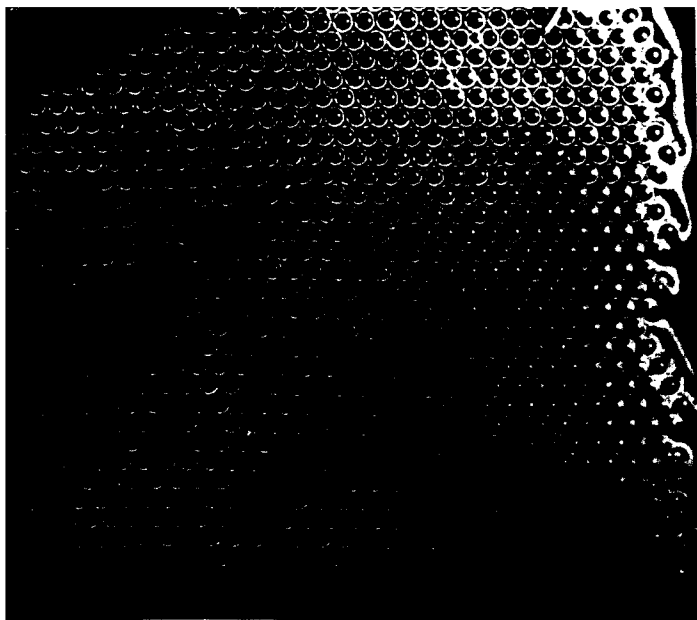


PLATE 6. A perfectly crystallised raft of bubbles.

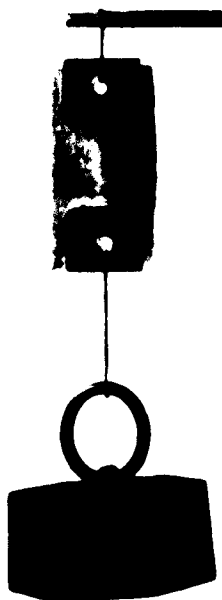


PLATE 7. A strip of "cellophane" $10 \times 5 \times 0.002$ supporting a 2kg. weight, its edges being stress-free. If touched by a needle-point, it breaks instantly when dry, but is unaffected when moist.

This section illustrates
THE ELECTRON MICROSCOPE (pp. 128-142)

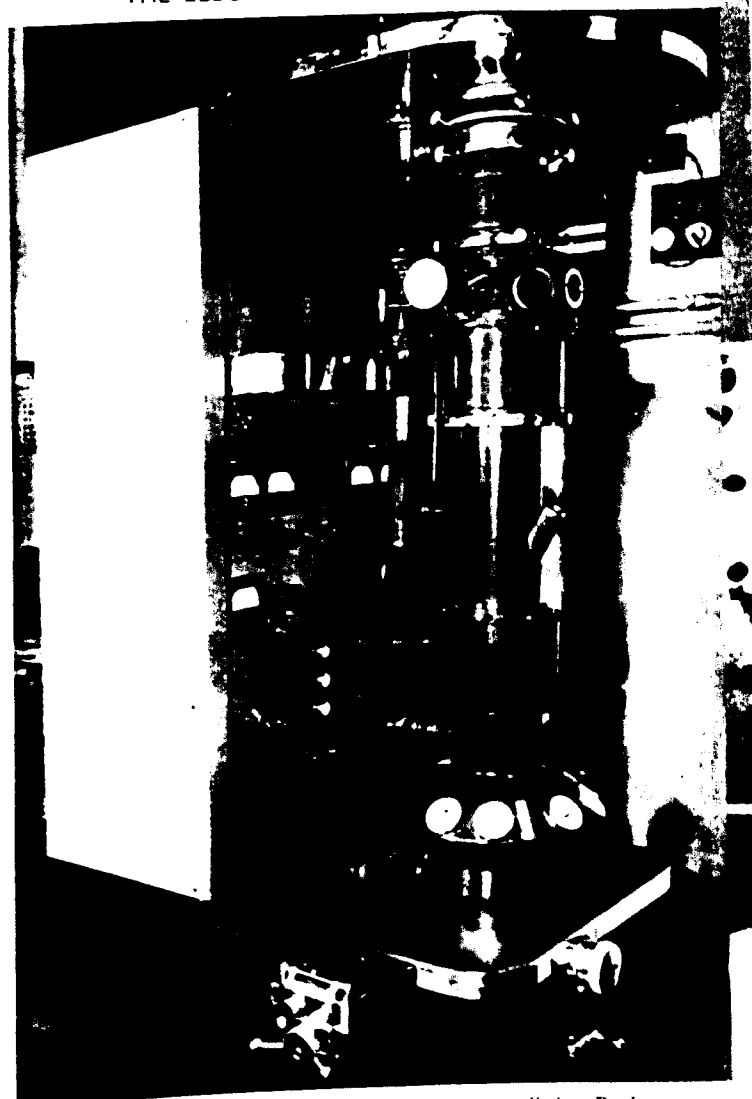


PLATE 8. The Electron Microscope recently installed at Rothamsted Experimental Station, Harpenden. It makes possible magnifications up to 20,000 diameters (see page 138).

ELECTRON
MICROGRAPHS



PLATE 9. Tobacco Mosaic Virus which causes a disease of tobacco plants. The rods, which may be the actual molecules, are about $1/65,000$ mm. wide. Final magnification, including some photographic enlargement, about 30,000 diameters.



PLATE 10. The Clay Mineral, Halloysite, mixed with Kaolin. The rods are the Halloysite. Until electron micrographs were taken it was not known whether this mineral was rod-like or plate-like. Final magnification, about 30,000 diameters.

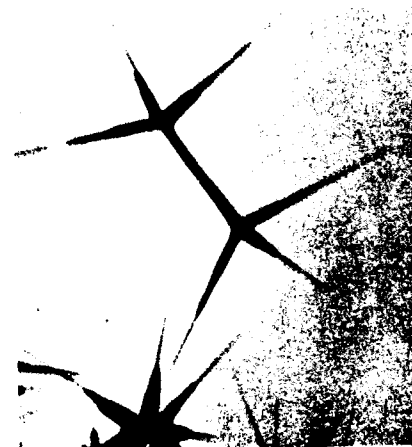


PLATE 11. Zinc oxide smoke, produced by burning metallic zinc, consists of long needle-like crystals of zinc oxide. The magnification is about 7,000.



PLATE 12. *Vaccinia*. The small oblong bodies are the active agent which produces immunity from smallpox, magnified 10,000 times.



PLATE 13. *Bacteria*. *B. Fluorescens*. Some internal structure visible. Magnification 6,000.

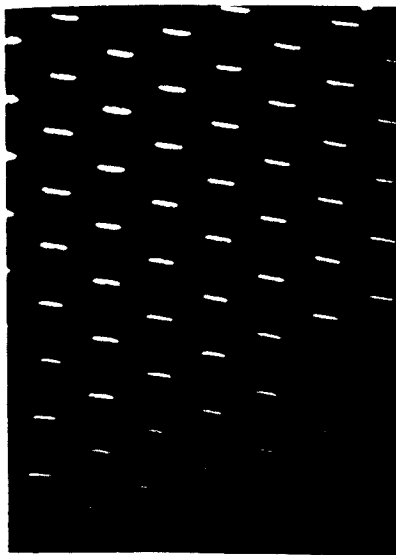


PLATE 14. *Diatom*. *Pleurosigma Angulatum*. The shell of this small plant is pierced by a regular array of small holes. The structure is just beyond the resolving power of an optical microscope. Magnification about 15,000.



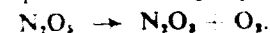
PLATE 15. *Diatom*. *Nitzschia Sigma*. Note the structure revealed within each hole. Magnification about 15,000.

cules, and the molecules may be characterised by their behaviour to chemical reagents (e.g. acids, alkalies, oxidising agents, etc.), and by their weight, usually referred (approximately) to the weight of the H atom taken as unity. Clearly, the weight of a molecule must be the sum of the weights of its constituent atoms. For benzene, since the weight of H=1 and C=12, the molecular weight must be 78. The determination of its molecular weight, by any one of a number of well-established methods, is an essential prelude to assigning a chemical formula to any new compound.

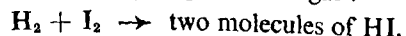
The chemist, then, is concerned to prepare these chemical compounds, which are almost innumerable, and to examine their properties. The organic chemist is concerned especially with the carbon compounds (since this element enters in a predominant way into the materials that build up living structures), while the inorganic chemist is concerned with the rest. There is one other main branch of the science, that of physical chemistry. This branch may be said to have started (about 1860) with quantitative measurements of the rates of transformation of chemical compounds, or rates of reaction, and this subject is still one of its chief pre-occupations. While the first two branches are concerned with the more stable products of these reactions, this newer branch sets itself to capture the fleeting intermediate states of the molecules that occur in the reactions themselves. In what follows I hope to set out the main ideas about the mechanism of these reactions, as they stand at the present time.

CLASSIFICATION OF REACTIONS

There are two main types of reaction. The first of these is the unimolecular reaction, which involves only one molecule, which undergoes some internal rearrangement or splits up into smaller molecules. A simple example of this is the decomposition of nitrogen pentoxide gas:



The second type is the bi-molecular reaction, which involves the coming together of two molecules and a re-arrangement of the atoms between them. For example, hydrogen gas and iodine vapour, if heated at 500° C. give rise to hydrogen iodide gas :



This particular reaction brings to our notice the concept of chemical equilibrium. When a certain amount of HI has been formed the reaction is found to come to a halt, or equilibrium. This is a dynamic equilibrium, which is reached when the rate at which the HI dissociates again into $\text{H}_2 + \text{I}_2$ just balances the rate at which H_2 and I_2 combine. At the start this "back-reaction" may be neglected, for the reason that the amount of HI formed is small, and therefore the velocity of its decomposition is also small (as we shall understand later). All reactions lead to such an equilibrium point, only in many cases it is so far displaced in favour of the products of reaction, that by the time it has been reached the original reactants have fallen to a concentration too low to be detected with our instruments.

THE IMPORTANCE OF CONCENTRATIONS

The concept of concentration just introduced "is a fairly common one in everyday life ; for example, we may say that a solution of a substance like sugar in water has a strength, or concentration, of so many grams per litre. In chemistry, however, since the unit is the molecule we prefer to express a concentration as the number of molecules per litre, or the number of gram molecules per litre. A gram-molecule is simply the molecular weight of the substance expressed in grams, and following the hypothesis of Avogadro it has been found that this number of grams of substance, whatever it is, and whether it is a solid, liquid, or gas, always contains exactly the same number (6.06×10^{23}) of molecules.

To consider the theory of gas reactions we have to start with the kinetic theory of gases. This postulates that a

pure gas is made up of identical particles, the molecules already mentioned, and these molecules are in a state of continual rapid motion (their velocity is about 1,000 metres per second). The velocity of the molecules increases with temperature and is responsible for the pressure exerted by the gas. Since the molecules are of finite size collision occurs between them in the course of their movements, and in a mixture of two gases like H_2 and I_2 , collisions of course occur between the different molecules H_2 and I_2 . If now we consider the case of the bi-molecular gas reaction (as the simplest) our first idea might be that the rate of reaction (e.g. $\text{H}_2 + \text{I}_2$) would be simply proportional to the number of collisions between molecules of the two reactants occurring in unit time, which we might call $Z (N_1 N_2)$. We write $Z (N_1 N_2)$, because if the number of collisions be calculated by the kinetic theory, then we find it comes out as a constant Z times the product of the concentrations, expressed in gram-molecules per litre, of the two reactant gases N_1 and N_2 .

i.e., we would expect

$$\text{velocity of reaction} = \text{constant } Z (N_1 N_2)$$

The velocity of reaction is defined as the rate at which the concentration N_1 decreases with time (which is, of course, equal to the rate of decrease of N_2 , since the molecule of type 1 always reacts with one molecule of type 2). Now a relationship of this type was one of the first to be discovered in this field of research, by Guldberg and Waage. The value of the constant yet remains to be determined ; if it is put equal to unity, that is, if we assume every collision leads to a chemical reaction, the calculated rate is about 10^{13} times greater than that usually observed. This problem was solved by Arrhenius, whose contribution may be described in the following way. In gases there will be molecules with all kinds of velocities, and kinetic energies. The number of molecules with an energy equal to or greater than a

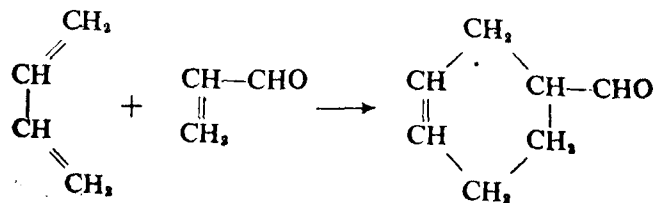
definite value E is then, by the kinetic theory, approximately a fraction $e^{-E/RT}$ of the total number of molecules. Here R is a universal constant, and T the absolute temperature (degrees centigrade $+ 273$). This expression, first derived theoretically by Clerk-Maxwell, has now ample experimental verification. Similarly in a mixture of two gases, the number of collisions in unit time in which the partners have energy equal or greater than E is $Z (N_1 N_2) e^{-E/RT}$. If we now assume that only molecules which collide with an energy equal to or greater than a critical energy E can react, we have a formula which gives a most successful description of many simple reactions (of which the $H_2 + I_2$ reaction is one). The expression now is

$$\text{velocity} = Z (N_1 N_2) e^{-E/RT} \quad (1)$$

In comparing this expression with experiment, it is usual to compare the calculated value $Z (N_1 N_2)$ with the corresponding empirical quantity. That is, the value of E is taken from experiment and only quite recently have attempts been made to calculate it. E is usually called the activation energy.

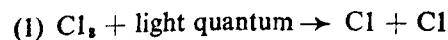
SPECIAL TYPES OF REACTION

Many reactions do not obey the simple theory that the velocity of reaction is equal to the number of collisions which possess the activation energy E . There is a group of reactions in which the rate is much *slower*, and this is so for many reactions between large complicated molecules. For example, a reaction of the type sketched (Diel's Synthesis):



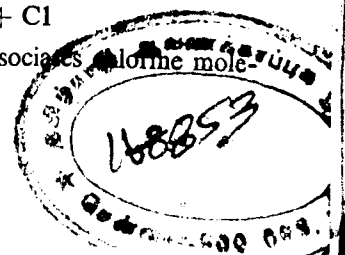
Here we might say that the molecules have to collide in a special configuration for reaction to occur, introducing a further restriction on our simple equation (1). During the last seven years it has become possible to calculate this restriction in principle, but the method involves statistical mechanics, and is beyond the scope of this article.

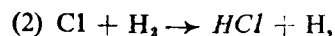
A further group of reactions proceed much *faster* than calculated on this theory, and the most important of these are perhaps the "chain-reactions." These reactions are responsible for many explosive reactions, e.g. those occurring in the petrol-air mixture in internal combustion engines, and underlie the methods of production of many of the modern synthetic rubbers and other plastics. The father of all chain reactions is the combination of hydrogen and chlorine in the presence of light, which possesses two characteristics. Firstly, we must note that in problems of this sort a beam of light is to be regarded as a stream of energy which is not continuous but rather analogous to a stream of bullets from a machine gun. In this analogy each bullet is a packet of energy of definite amount (dependent on the colour of the light), which is called a quantum. Normally speaking, as Einstein showed, one quantum of energy would be expected to bring one molecule to reaction, but in this case one quantum brings about a million molecules to reaction. Secondly, this quantum of light acts as a trigger to start off an exceedingly rapid reaction, which proceeds with explosive violence. Nernst showed these results could be explained by assuming a reaction "chain," in which the products of the initial reaction are so active that they cause further reaction to occur. We can divide the course of the reaction into three steps.



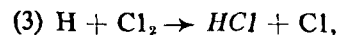
i.e. a quantum of light energy dissociates chlorine molecules into atoms.

Acad. Sci. 1926

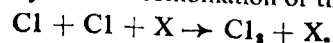




a chlorine atom reacts with a hydrogen molecule to give hydrogen chloride plus a hydrogen atom.



the H atom produced by step (2) reacts with a chlorine molecule, to give hydrogen chloride plus a chlorine atom, which can then react with H_2 according to step (2), and so on. In this way a chain of alternate steps (2) and (3) may be set up, each step or link giving rise to one molecule of the product HCl. One quantum serves to set off this chain, which may possess as many as a million links. That is, one quantum may give rise to the production of a million HCl molecules. The reaction chain can only end when either all the hydrogen and chlorine have been used up, or by the removal of the chain carriers, which are H atoms or Cl atoms. For example, if two Cl atoms meet in the presence of a third body, X, we may have re-combination of the atoms

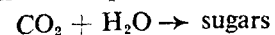


The third body is necessary to remove the energy liberated when the two atoms combine, otherwise the atoms will immediately fly apart again. Such collisions of three molecules are rare (X may also be the wall of the containing vessel).

The important propagation steps (2) and (3) proceed with almost a hundred per cent efficiency, the activation energy for free atoms always being nearly zero. Free atoms, which possess an unsaturated valency, as one might expect are always much more reactive than the ordinary saturated molecules. Because of this reactivity, of course, they cannot be isolated and kept in a bottle, but at ordinary temperatures put in only a momentary appearance, requiring very special methods for their detection.

Since the combination of hydrogen and chlorine occurs under the influence of light it is called a photo-chemical reaction. The "activation energy" in this

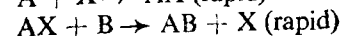
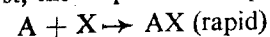
case is the energy required to dissociate chlorine molecules into atoms, and is obtained from the light energy. The case is distinct from the combination of hydrogen and iodine already discussed, which is called a thermal reaction, because it is brought about through the agency of heat, which increases the kinetic energy of motion of the molecules and also the fraction of collisions with energy equal to or greater than the activation energy. While thermal reactions are the basis of most industrial processes, it is a photo-chemical reaction that forms the corner-stone of life on the earth. In the green leaf, the light of the sun is used to perform the following reaction :



This reaction is brought about by the substance Chlorophyll, which acts as a catalyst, converting the light energy into chemical energy (in the sugars), which may subsequently be used again as food. Since coal-measures arise from fossilised plants, when coal is burnt we are merely re-liberating the energy of the sun stored up in this way millions of years ago. Claims have been made that this reaction has been conducted in the test-tube, using catalysts based on the metal nickel, but these claims are still open to doubt.

CATALYSTS

We have referred to chlorophyll as a catalyst. Now a catalyst is defined as any substance which will accelerate the rate of a reaction, while itself remaining unchanged at the end of the reaction. Its function appears to be to provide a path for the reaction, of much lower activation energy than the reaction would normally have, and this it appears to do by the transitory formation of intermediate compounds. Suppose the reaction $\text{A} + \text{B} \rightarrow \text{AB}$ is slow, and X is a catalyst, then a possible simple model is

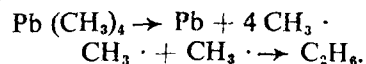


leading to an overall reaction $\text{A} + \text{B} \rightarrow \text{AB}$ that is fast, compared with the case when X is absent.

As to the nature of X, it may be a small molecule, e.g. iodine, I_2 catalyses the thermal decomposition of the ethers (of which the anæsthetic ether is one example). It may be a large molecule like chlorophyll, or like the large protein molecules (enzymes) which catalyse the reactions that occur in the body. Or it may be a surface, particularly a metallic surface, which forms a special type of chemical compound with the reactant molecules. Metallic nickel catalyses the addition of hydrogen molecules to unsaturated oils, a reaction which is used in the production of margarine. In all cases it appears that in some mysterious way the catalyst loosens the chemical bonds in the reactant molecules, so that they may easily rearrange themselves among the constituent atoms to give the products.

FREE RADICALS

I have already referred to a reaction which involved atoms (the $H_2 + Cl_2$ reaction). This idea has recently been generalised, through the discovery of free radicals, which are molecules which through the loss of an atom or atoms have become very chemically reactive. They are said to possess a free valency. For example, Paneth showed that if the saturated molecule, lead tetramethyl, be heated, it decomposes to give free methyl radicals (which are methane molecules minus an H atom). The radicals exist for only a fraction of a second, before they combine to give ethane. The equations are



Since this work the transitory existence of free radicals has been discovered in many reactions, and they are important as chain carriers (behaving like the atoms H and Cl in the case above). They are important in processes like that by which hydrocarbons are cracked down to give smaller molecules used to produce fuel oils, and in the reactions by which synthetic rubbers are produced.

CALCULATION OF ACTIVATION ENERGY

I have said that many simple reactions appear to follow the rule for their velocity of reaction

Velocity = Number of collisions with energy equal to or greater than E

= Total number of collisions $\times e^{-E/RT}$

The total number of collisions can be calculated and to test the agreement with experiment the quantity E was taken from experiment (from the way that velocity alters with T, the temperature). Before we can claim full understanding, however, we should be able to calculate the activation energy E from our knowledge of chemical forces.

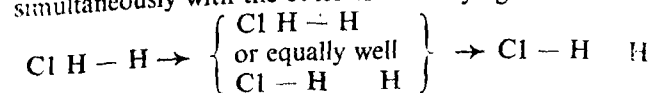
At the present time it cannot be claimed that great progress has been made with the actual calculation of E, but it would appear that the conceptual basis of the theory has been laid. If we consider one of the simplest reactions (in the chain already referred to), $Cl + H_2$, we may visualise the following steps:

(1) The Cl atom approaches $H-H$ along its axis (since it may be shown that it is strongly repelled if it approaches along other directions).

(2) When the Cl has approached to a distance roughly equal to the $H-H$ bond length, it starts to exert a profound attraction for the nearest H, and causes the $H-H$ bond to stretch and so become weaker.

(3) A configuration is reached in which the distances are such that we can no longer refer separately to the Cl atom and the H_2 molecule, but must view the complex as a single entity of three atoms. This is the "activated complex," with a life of about 10^{-13} sec. It cannot, of course, be isolated because of its fleeting existence.

(4) A chemical bond forms between Cl and H, simultaneously with the outer H atom flying off.



Now, a chemical bond of this type is due to the sharing of two electrons, one from each atom, and in principle it is possible to calculate the energy of this bond. In principle, also, this calculation may be carried out for the activated complex. In practice, however, the mathematical complexity of the problem forces the use of most drastic approximations, which cannot hope to give quantitative results. In fact, for the purposes of numerical computation of E it is at present the practice to use purely experimental data to describe the properties of the stable molecules (e.g. H_2 and HCl above), and to use the theory as a method of interpolation to ascertain the energy of the activated complex. The activation energy E is then simply obtained by the difference between the energy of the activated complex and that of the initial reactants. In the above case, the theory shows that an important factor in E is the energy required to stretch the $H-H$ bond and weaken it sufficiently for it to "switch over" to the Cl atom.

THE CONCLUDING TOPIC—IONIC REACTIONS

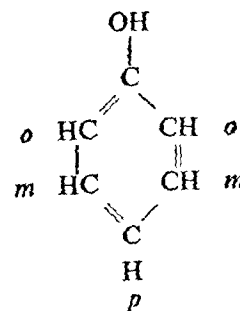
Up till now we have carefully avoided the question of ions, that is, atoms which have lost or gained one or more electrons and so become positively or negatively charged with electricity.

e.g. Sodium atom minus an electron equals the positive sodium ion, $Na - e = Na^+$

or Chlorine atom plus an electron equals the negative chlorine ion, $Cl + e \rightarrow Cl^-$

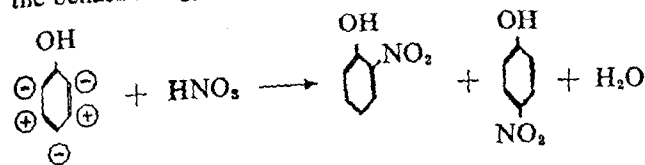
Most of the salts, of which the prototype is common salt, $NaCl$, are made up of ions which are bound together in a regular arrangement in their crystals. When the crystals are shaken with water, the water helps to lessen the electrical forces holding the ions in the crystal, which dissolve in the water. Now, reactions between ions of opposite sign in water are usually very rapid, as the electrical force of attraction between the ions helps to overcome the activation energy which is present (just as

it is in the simple non-ionic cases like $H_2 + I_2$). In fact, some reactions like that of $Na^+ + Cl^-$ in water are so rapid that no one has succeeded in measuring their rate, to date. Two ions of the same charge, however, have usually a very slow rate, as now besides the ordinary activation energy the electrical repulsion between the like charges has to be overcome. The important substitution reactions of benzene are also reactions of an ionic type. Take, for example, the nitration of phenol, a reaction of great importance in war-time, since it yields picric acid, used in many explosives. As a first step we might expect three kinds of nitro-phenol, corresponding to reaction at the three carbon atoms marked *o*, *m* and *p*.



Phenol (Hydroxybenzene)

Actually, very little of the *m*-type is obtained, but mainly *o* and *p* types. This is because the hydroxyl (OH) group induces an alternating electrical polarity in the benzene ring, as in the diagram.



The reactive species of the nitric acid, formula HNO_3 ,

is possibly the positive ion NO_2^+ , arising by the dissociation



This NO_2^+ then preferentially reacts with the carbon atoms labelled *o* and *p*, since these are negatively charged and their electrical attraction for the NO_2^+ helps to overcome the activation energy and give a rapid reaction, as in the example mentioned above. On the other hand, the repulsion of like charges serves effectively to slow down reaction at the *m* group.

This then concludes our brief survey of the subject of reaction rates. Some of the topics are still in the controversial stage, and no attempt has been made to discuss points of detail. The important topic of solid reactions has been omitted completely. I hope, however, that sufficient has been said to convey to the reader the main lines of advance in this rapidly developing field of research.

MEDICAL NEWS

BETTER DRUGS FOR BIGGER BUGS

MOST people nowadays have got it firmly into their heads that epidemics of disease are due to germs—bacteria as the scientist calls them when he is being professional, or bugs as he usually says when “off the record.” But that is only part of the story. An average bacterium measures a thousandth of a millimetre across, but there are both smaller and larger infective agents. The smaller are the viruses, such as those for influenza or smallpox; they are about ten times smaller (linearly). And about ten times bigger than the average bacterium, there are the trypanosomes, the causative agents of sleeping sickness, kala-azar, and a number of other tropical diseases. They are big enough to be seen in fair detail with good microscopes, and we know that they have quite an elaborate structure. They are sack-like or cigar-shaped creatures, with a filament which they can waggle, and a thin fin-like membrane, by which they swim; and inside there is always a special round blob of jelly called the nucleus, and various granules and so on.

In the last year or two, science has discovered a new weapon against the bigger bugs; and this may be very important in civilising the jungles of the Far East.

The way these new drugs were developed is a good example of how research is done these days. Some workers under the late Professor Warrington Yorke, at the Liverpool School of Tropical Medicine, got the first hint. After testing a large and varied collection of substances, they found that one of them, technically known as a diamidine, was rather poisonous to the sleeping sickness “germ.” A big research team under Dr. Ewins, of the famous firm of May & Baker, immediately took the matter up. Yorke’s active substance

had two chemically-reactive groups of atoms held together by a rather unreactive chain. Ewins' team manufactured a large number of similar substances, with the same active groups but different chains; and Yorke tested them out on mice infected with sleeping sickness. Two or three of them turned out to be much better than the old arsenical compounds, since they kill off the "germs" without doing much harm to the patient. The "patients" were mice, of course; but there has

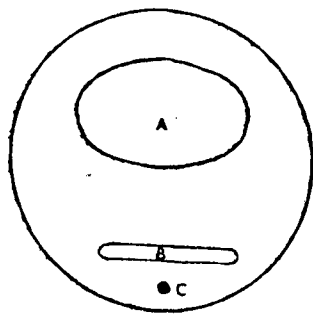


FIG. 13

The size of things under the microscope. The large circle is a red cell from human blood; A, the head of a human sperm; B, the germ of tuberculosis; C, a virus. On the same scale, the largest molecule would be a just visible speck.

already been time to try out the best drugs on a few men suffering from tropical diseases, and so far the results have been very good.

IMITATING LIVING CHEMISTRY

These new sleeping sickness drugs have been developed only by a great deal of hard work, and luck in hitting on the right compounds. Drug research has been an essentially hit-or-miss affair, "let's try it and see," with

many disappointments in its path. Anybody who saw the film, "Dr. Ehrlich's Magic Bullet," will remember how, when Ehrlich was searching for a drug to combat syphilis, and eventually hit on salvarsan, he called it "606" because it was the six hundred and sixth attempt. The discovery of Penicillin was quite accidental; the production of the sulphonamides took years of work—and, funnily enough, when the first good one was found, it turned out to have been known chemically for nearly thirty years, only no one had thought of testing it against bacteria!

Investigation of the way in which sulphonamides work in their anti-bacterial fight has, however, given the scientist an entirely new and quicker approach to this business of drug invention. It has turned out that bacteria need vitamins just as much as we do, only often their requirements are rather different from ours. One of these vitamins, p-aminobenzoic acid, is very similar in chemical structure to sulphanilamide, the simplest sulphonamide drug, and germs do not distinguish between them: they take in either indifferently to build up their internal "works." But only the vitamin fits in with the rest of the machinery; the drug slips into the same place and jams the whole thing up. So the new line of investigation is to start making substances chemically similar to necessary vitamins but just not quite like enough: then in they go in place of the vitamins and the germ's living processes come to a stop. This method involves finding out the vitamin requirements of each different kind of disease bacteria, a thing which has not yet been fully done. But the method is already leading to useful results.

The same idea is now being applied in the control of the human body itself. When skin is injured by cutting or burning, a substance called histamine is liberated into the blood and causes the local redness and swelling. If the wound is large, the effects are generalised throughout the body: the blood pressure falls, the patient becomes

pale and out of breath, and the symptoms of surgical shock appear. Histamine is also liberated into the blood stream whenever foreign protein gets into the blood through an abnormal intestinal lining, or through the injured mucous membrane of the nose, and causes mild convulsions, as in hay fever, or spasm of muscles in the lungs, as in asthma, or skin rashes and headache, as people who are sensitive to such foods through congenital abnormality react to strawberries or crayfish, or milk.* The precise severity of the symptoms probably depends on the actual amount of histamine liberated. It appears a mere useless oddity that the body should respond in this manner: if we could control or stop the reaction it would be all to the good. Up till now in many of these cases there has been no very helpful treatment, but workers at Columbia University, New York, are now experimenting with histamine imitations, with promising results. They have just reported that a substituted ethylene-diamine will prevent all the actions histamine has on muscle—and many of the symptoms it produces are due to such an action. Apparently histamine goes into the muscle fibre and combines with some particular part of it to cause the reaction, but when the drug is also present it enters the muscle instead and occupies the same place without producing any response on its own, merely preventing the histamine from combining.

This idea of producing substances similar to, but not identical with, essential natural substances, and so controlling living processes by this method of competitive inhibition, seems likely to have a big future. In diseases where glands are oversecreting, where, for example, the thyroid is swollen up in the neck and producing too much thyroxine, it may be possible to cancel its ill-effects by injecting a synthetic near-imitation, which will block some of the thyroxine-combining points in living tissues. It may, in fact, be the first step to a control over the physical development and bodily shape of man.

* See article on "Allergy" on page 157.

ANTIBODIES

Another way of combating histamine which is now being tried is rather cunning. This depends on the fact that when a foreign protein (common examples are egg-white, the flesh part of meat) is injected into the blood, the body begins to build up another protein which has the special property of combining specifically with the foreigner and neutralising it so that it can do no harm. These neutraliser proteins are termed antibodies; their specificity is such that one which neutralises duck egg-white has no effect on hen egg-white, for instance. On the other hand, if a chemist adds a special chemical grouping on to one of these proteins he often makes it from the antibody's point of view into a totally new and strange antagonist, which requires a new and special antibody; and this special antibody will not only combine with the strange protein, but also with the isolated grouping of atoms, before the chemist has fixed it to anything.

What the chemists have been doing is attaching histamine to proteins and injecting the products. Antibodies to histamine-protein are produced which are also capable of neutralising histamine by itself. People who have been so immunised ought then to be symptom-free when histamine is released in their bodies, as they have an antibody ready to mop it up as it forms. Whether the method is really any good, it is still too early to say—it is still experimental, in the laboratory.

Another piece of antibody news is very startling. Professor Linus Pauling, one of America's leading chemists, has discovered a possible method for making antibodies artificially, so that in the future it may be possible to start an antibody industry for the manufacture of these protective anti-bacterial substances, ready for injection into people who need them. His work, if it is confirmed, will throw light also on how the body makes these special substances. Apparently they are formed by modifying the shape of some of the

proteins normally present in the blood, the molecules of which consist of long chains of atoms folded up in ways not yet understood. Pauling's method is to heat the blood-proteins slightly in the presence of the bacterial poisons (which are mostly proteins, too). This makes the chains unfold; and on cooling they fold up again, apparently in a different form from before, but one influenced by, corresponding to, and able to neutralise, the poison which has been used.

Of course, even should this method turn out a success the present methods of inoculation and immunisation will still be of the first importance, because they build up resistance to the disease germs before the disease begins, and so nip the whole trouble in the bud. Passive protection, by the injection of suitable antibodies when the disease has already started, is definitely only second-best.

In this connection, an advance in immunisation treatment recently reported by two American doctors is interesting. Whooping cough is a very dangerous disease for young babies, but they cannot be effectively inoculated against it before the age of seven months, as they do not develop the power of forming the appropriate antibody until that age. The new idea is to inject the mother before the baby is born. It is known that antibodies can pass from the mother's blood into that of her child, and if the concentration of antibody in the mother is raised sufficiently high, by immunising her, enough may get across to her baby to keep it immunised for a while immediately after birth. Probably the antibody would not last the child the whole seven months: we shall have to think of another scheme for that.

PINS AND NEEDLES

Until fairly recently, the full explanation of the familiar stiffness one experiences after sitting for some while in one position has never been given. Thousands of people had had their "foot fall asleep," and felt the pain and

stiffness and temporary partial paralysis on getting up, but, as so often with the common everyday troubles, the medical explanation was not forthcoming. In the last ten or fifteen years, however, largely as the result of the work of Lewis and his collaborators at University College Hospital, London, a number of new ideas on the importance of the amount of blood reaching the tissues has spread through medicine. It has become clear that, to keep alive, every tissue needs a certain minimum amount of blood bringing oxygen, and an extra ration during periods of special activity; and that though, normally, blood vessels are large enough pipes to bring this, in various diseases or special conditions it is not so. The tissues are oxygen-starved, since the blood supply is now inadequate, and liberate substances into the blood which cause pain if they are allowed to collect, and are not washed away.

When your foot falls asleep, what has really been happening is that you have been squashing the artery which carries blood to the sciatic nerve, the main nerve to all the leg and foot, which runs down the back of the thigh and in the buttock. Consequently, after a time, the relatively oxygen-starved nerve feels rather feeble, and when you try to get up, which means sending messages down the nerve to the leg muscles, it just refuses to transmit them until it has recovered; and it similarly refuses to pass messages from the leg up to the brain, with the single exception of pain messages, which are always hardest, and the last to go. This explanation has only recently been realised, because, until recently, no one thought that the blood supply of nerves was of much importance.

Another example of inadequate blood supply is found in arteriosclerosis, the "hardening of the arteries" of middle age. What really happens is that, for some unknown reason, the arteries, particularly those of the legs, become "furred up": deposits are laid down on their lining, thus narrowing them gradually, until finally,

although a blood stream is flowing into the legs, it is not big enough, and the legs, particularly the feet, become cold and swollen and painful, and in effect begin to die from lack of blood—a picture known as gangrene.

This principle of inadequate blood supply is finding wide application in all sorts of places. It has long been known that lack of blood to the heart muscle causes pain in the heart—angina pectoris—felt over the left shoulder and down the left arm. The poisoning that sometimes occurs during pregnancy may again be due to release of toxins from a dying placenta receiving an inadequate blood supply.

AVIATION MEDICINE

The performance of fighting aircraft puts strain on the human body which it can only just bear. The main problems (at any rate as far as the public has been allowed to know) are the lack of oxygen, the low atmospheric pressure and the cold at high altitudes, and the centrifugal forces caused by turns at high speed. The design of breathing masks which stand up to the low temperature is a ticklish business. The warmth of the crew should present no great scientific problems; there is plenty of heat available from the engines, and the task is essentially one of designing a system which will lead it to the places where it is wanted.

The low pressure is not so easily dealt with. In about 10 minutes, a modern fighter may rise from the ground to about 35,000 feet. Up there the atmospheric pressure is only a quarter what it is at sea-level. The provision of extra oxygen does not fully meet the situation. There is always a small amount of air dissolved in the blood; when the atmospheric pressure is reduced, the amount of air which the blood can hold in solution becomes less, and some of that which had been dissolved appears as bubbles, like those in a bottle of soda water when you take the cork out. The minute bubbles of oxygen do little harm because the body can immediately absorb

them again. But the other main constituent of air is nitrogen, and if bubbles of nitrogen form in the blood, they are difficult to get rid of and cause the agonising condition known as "bends." The trouble is well

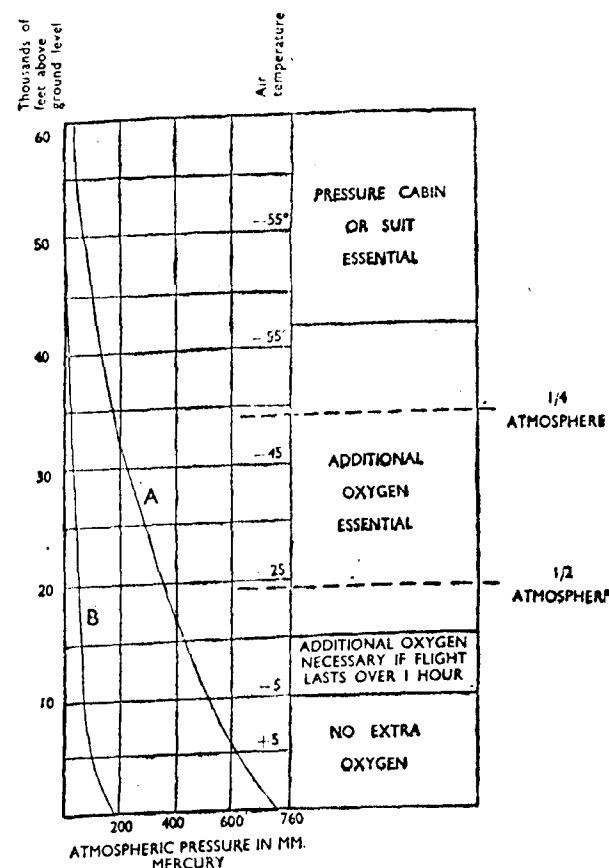


FIG. 14

How air conditions vary as one rises up off the airfield. (after Matthews.) Curve A: decrease of total air pressure; Curve B: decrease of oxygen in air.

known to divers, who, of course, also undergo decompression when they rise to the surface from a deep dive. They normally avoid bends by ascending slowly, to give time for the excess nitrogen to escape gradually. But that way out is clearly impossible for pilots. According to American information, however, there are two methods which entirely get over the difficulty. One is pre-oxygenation; if a pilot breathes pure oxygen for

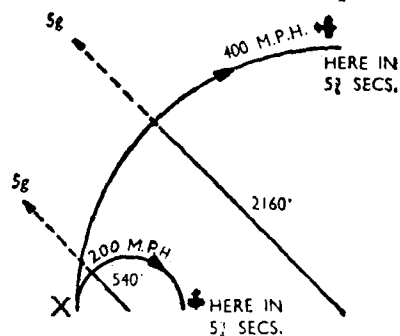


FIG. 15

When a plane makes a turn, the pilot feels pulled out away from the centre of the circle he is turning along, and the strength of this pull depends on the speed of his flight, and the radius of the circle. Normally he cannot stand a pull greater than five times gravity, and this diagram shows a fast and a slow plane turning, so that the pull is just this for both. (Sharper turns would increase the pull further.) Clearly the slower plane can make a sharper turn without upsetting the pilot, and so can escape the fast plane. Human limitations become more important than aeronautical engineering skill. (after Matthews.)

some time before making a flight, the nitrogen is entirely lost from his blood before he leaves the ground. The other is simply selection of suitable personnel. It turns out that people vary very much in their liability to bends, and the susceptible ones can be weeded out by testing them in a decompression chamber.

No satisfactory cure for the fourth problem, the "black-out" when turning at high speed, has been

published. The centrifugal force produced when pulling out of a power dive or when turning at speed may be several times that of gravity. In effect, the pilot becomes five or six times heavier than he normally is. The most important result is that the blood may become too heavy for the heart to circulate; it is driven away

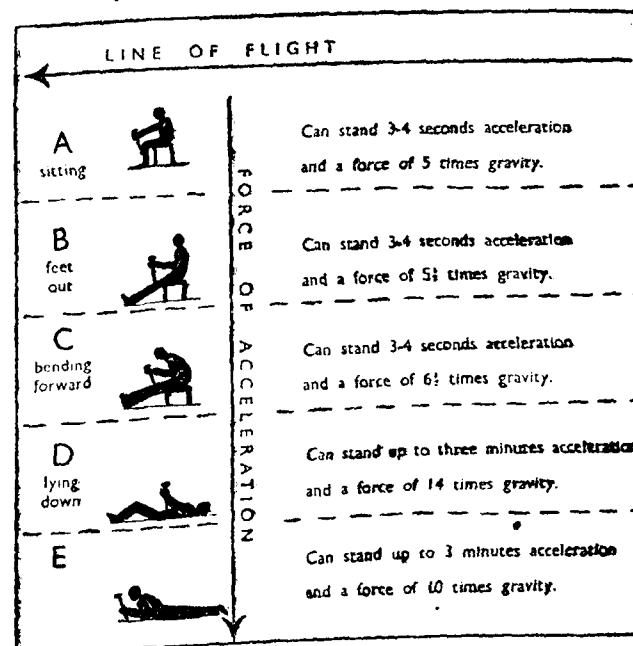


FIG. 16

The fighter pilot can bear sharp turns and sudden accelerations better in some postures than in others. (after Matthews.)

from the head and the pilot faints. There is a time factor involved; most people can stand a force of five times gravity for about $4\frac{1}{2}$ seconds, and one of seven times for about 2 seconds. There is some variability in the capacity to withstand such forces, but no individuals are as good as we should like. The Germans have

published various suggestions for increasing resistance. Perhaps the most popular among pilots was based on the idea that if the stomach was full after a hearty meal, there would not be so much room for the blood to flow away from the head into the abdomen. Rather more promising sounds the use of drugs like pituitrin and adrenalin, which contract the smaller blood vessels. Mechanical devices for constricting the legs and abdomen have also been suggested, for instance pneumatic belts or trousers. The Germans seem to have also experimented with a "water-suit"; the pilot wears a complete waterproof suit, the space between the skin and the suit being filled with water, which acts as a cushion so that the acceleration forces are transformed into a uniform pressure over the whole surface of the body; it is said to improve resistance to black-out but to be "unsatisfactory for other reasons."

SHIPWRECK TROUBLES

Modern warfare on a global scale involves an unprecedented strain on medical knowledge. Each battle area has its own special medical problems, and in addition the conditions inside submarines and tanks, in aircraft and on the sea need special consideration. The Medical Research Council has recently issued a booklet as a guide to the preservation of life at sea after shipwreck, which discusses not only the dangers of seawater "burns" and "immersion foot" (due to prolonged soaking in cold sea-water) and the general conduct of a ship's lifeboat, but also the occasions on which it is advisable to administer methedrine or amphetamine tablets (benzedrine-like drugs) to the crew to keep up their spirits. These drugs lessen feelings of fatigue and exhaustion, promote alertness, and prolong the will to live; and they enable one to manage with less sleep.

The great problem for men at sea, though, is the question of drinking-water, and various attempts have been made to get it from the sea. Dr. Parker, of the

Water Pollution Research Laboratory, has summarised the various methods which have been tried.

Probably the most hopeful method is the simplest: to boil the water, and cool and condense the steam in a still. The difficulty is to design a still which is light, very steady, and efficient. At present, it seems to be possible to get about five or six volumes of pure water for each volume of spirit burned as fuel, and the stills now in use will burn almost anything, including driftwood, if one has driftwood.

Various other methods, not requiring such complicated apparatus, have been tried. For instance, some jellies (e.g., silica gel) will absorb water vapour, and give it out again on heating; but the best one can hope for is for the jelly to take up about one-fifth of its own weight, so that the weight of jelly plus fuel to heat it becomes excessive. Again, some substances will dissolve in warm sea-water, but, when the water cools, separate out again as crystals which contain pure water which they give up again on heating. But again the process is less efficient than distillation. One could make pure water by freezing salt water and re-melting the first-formed ice; but once more the refrigeration apparatus, and the fuel to run it, take up more room than the water they could make. For those shipwrecked on the Northern sea-routes, sea-ice when melted by the sun can, however, be a valuable addition to the water ration.

A different method would be by pumping sea-water through a filter; some membranes (the so-called "semi-permeable" membranes) will let through the water but keep back the salts; but naturally the pores have to be excessively fine, and pressure required to pump the water through at any appreciable rate is so great that no membranes are known which will stand up to it satisfactorily.

A final method is an adaptation of the common water-softening devices which are in general use for adjusting the hardness of ordinary domestic water supplies. There

This and the next two pages illustrate METALS (pp. 63-80)

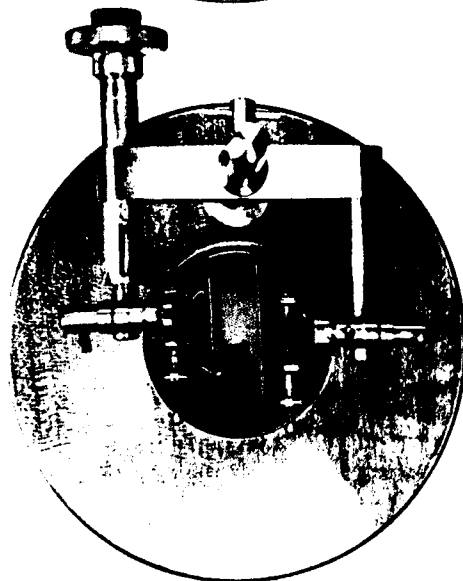
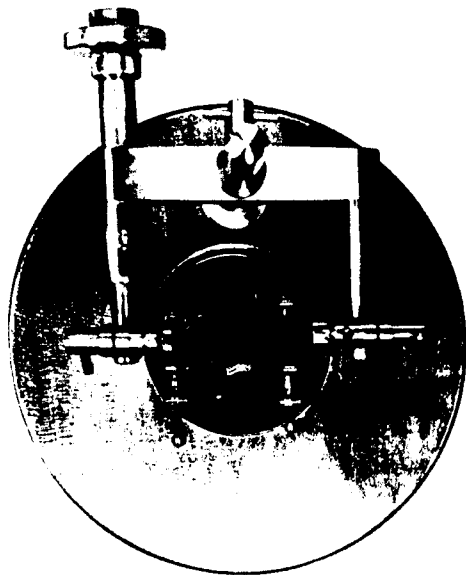


PLATE 3. Rafts before and after a succession of "slip" movements.

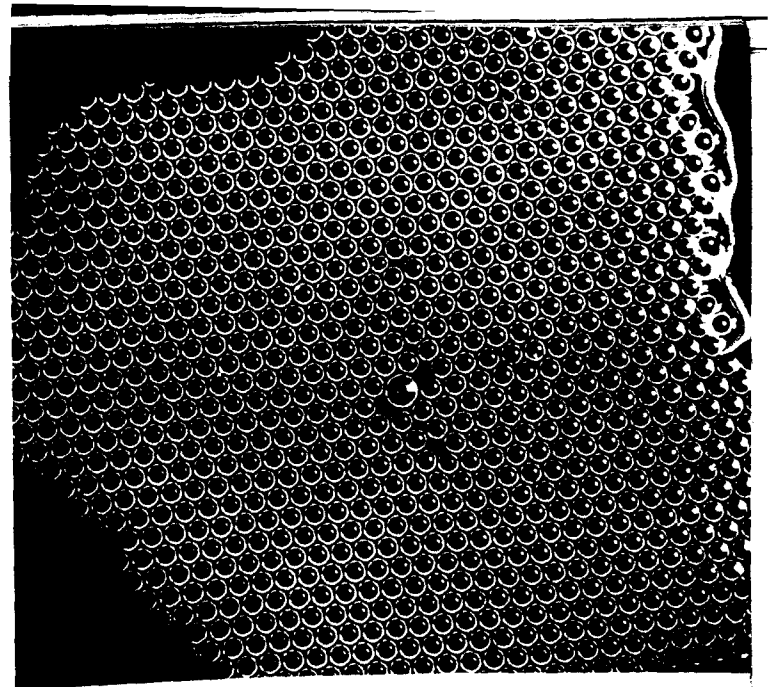
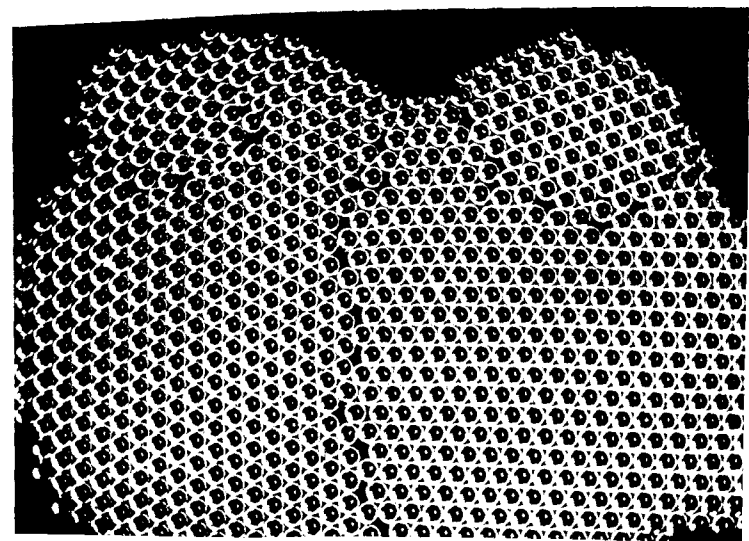


PLATE 4. A polycrystalline raft.

PLATE 5. The effect of a foreign atom.



are certain substances which will exchange bases with water which passes over them; for instance, they will extract calcium and magnesium and replace them with sodium. Recently new materials with similar properties have been discovered by workers on plastics. Some of these will remove sodium, calcium and magnesium, replacing them with hydrogen, which makes the water acid. It would still not be fit to drink. But the plastics chemists have developed acid-exchanging resins, which will remove the acid and replace it with the "hydroxyl," which, together with hydrogen, makes up ordinary water. Pure water can be made from sea-water in this way; but so far the volume of exchange materials required is about the same as the volume of pure water obtained—so nothing is gained. However, the R.A.F. and the Fleet Air Arm use one of these base-exchange water purifiers—decalso—as part of their equipment.

The American National Research Council has also been studying the problems involved. They find that men on rafts can manage on 500 cc. (rather under a pint) of drinking water a day, provided they live on a very low diet, only 500 calories, as against the normal minimum of 3,000 for people of sedentary life. They also point out that salt water can be drunk in very small quantities by one or two special methods; for instance, the mouth can be rinsed out with salt water when it gets dry, and this may mean a water gain of 10 cc. Concentrated tomato juice can be provided which is suitable for a five to one dilution with sea water to make a palatable drink. And the type of food provided is important. Meat is bad, since its end-products require water for their excretion. Fat, on the other hand, is good as a concentrated energy source which also yields more water inside the body; but one cannot stand a diet of fat alone—the maximum is half-and-half with sugar. American shipwreck rations are therefore largely a sort of butterscotch made from sugar, fat (20 per cent.) and citric acid for flavouring, and vitamin

tablets are also provided, chiefly for their good psychological effect.

British rations are built on the same principle, but are more varied in character: high fat (20 per cent.) biscuits, butter, chocolate (40 per cent. fat) and full cream sweetened condensed milk (20 per cent. fat).

These results have been obtained in the first place by studying the water balances and general health of groups of "back-room" boys who have volunteered to try to live on the various types of rations which have been tested. These human guinea-pigs deserve credit for the discomforts and sufferings they voluntarily undergo in the cause of medicine, and to help the men at sea.

SURGICAL MIRACLE

A recent report from the Johns Hopkins Hospital, Baltimore, tells a fascinating story of what modern surgery can do. About fifteen years ago, a little girl accidentally swallowed some very strong alkali, which ruined her throat right down to its entrance into her stomach. The lining was killed and sloughed off, but soon the raw area began to heal, and such being the extent of the damage, the huge scar that resulted blocked the food passage as it developed, and her throat became sealed and useless. This situation demanded urgent surgical treatment if she was not to die of hunger and thirst, and fortunately a fairly well-known operation was available to put things right, because throat blockage occurs now and then from various causes and has consequently stimulated study. So the surgeons of Baltimore got to work and cut out the now useless length of throat, making a direct opening from the outside of the stomach through a hole just at the border of the ribs on the left side: henceforth that was to be the child's mouth, and through it she would have to put all her food when it had been suitably chewed. At the same time, just the upper end of her throat being still serviceable, they made another hole at the bottom of

her neck, and connected the remains of the throat to it, so that if, for instance, she drank a glass of water, it would

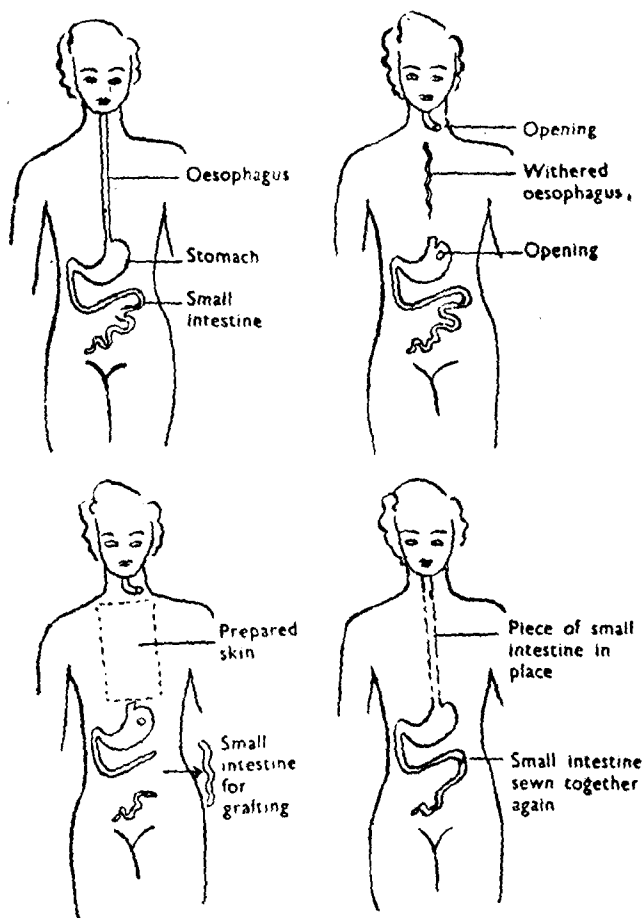


FIG. 17

Making a new oesophagus.

come pouring out through the bottom of her neck, if the stopper were taken out.

From all this the child made a very good recovery, and went home. She was able to go to school and lead a fairly normal life for the next ten years, during which the surgeons thought things over, and read what their colleagues in other parts of the world were doing. As a result of this study, they were then able to invite her back to hospital to be made into more of a normal person: they were going to try and join the hole in the neck with the hole in the stomach and so in effect give her a complete new throat and through-way from mouth to stomach. The operation had to be done by stages, which lasted in the end a total of three years. The first stages were the production of more skin in the areas around the holes, and down the front of the chest, so that a tube of it could be rolled up all the way down. When this was ready they took out a suitable length of intestine, snipped it off and joined the main ends, and sewed the isolated piece at one end to the neck-hole, and at the other to the stomach hole. The extra skin of the skin tube served as a wrapping.

The situation when everything had healed was that she then had a new throat down the front outside her chest, but inside her skin. The piece of intestine had settled down to its new job and learnt to help with swallowing like a real throat, and she not only had this convenience, but also the consciousness that she was more like everybody else; the photograph the surgeons took of her when she was recently seventeen shows their good workmanship—it is impossible to tell that anything has ever happened to her.

The operation sounds astonishing but is really little more than a bold extension of the principles of gastric surgery, operations which are often regarded as highly dangerous but in reality, in suitable patients, are comparatively mild. The present custom is to do many of these under local anæsthetic only, and the patient can take a cup of tea while still on the operating table.

GRAFTING LEGS

Surgical operations of such excellence are possible only as the result of years of research, often involving animal experimentation. The Russian biologist Lapschinsky has recently reported one such piece of basic surgical investigation, the successful replacement of an amputated leg of a rat by a new leg taken from another animal. It is unlikely that the method will soon come into use among human beings, if only because most people who have legs prefer to keep them themselves instead of donating them to their friends. But Lapschinsky's experiment is nevertheless of considerable practical and scientific importance. Cases sometimes arise in which a surgeon has to remove from one patient an organ, or part of an organ, of which another patient stands in need. Up till the present, attempts to graft material from one individual to another have nearly always proved unavailing in man or in other warm-blooded animals. The lack of success has been so continuous that it is generally believed that attempts to graft are hardly ever worth while—the best that can be hoped for is that the graft does some temporary good, before the body casts it off and destroys it. But in the last few years this doctrine is being called into question. It has been found possible to graft the cornea, the clear skin covering the pupil of the eye, from one individual into another, and even from a recent corpse into a living man suffering from blindness due to degeneration of his cornea. This is the only practical exception at the moment: what is required is more investigation not only by surgeons, but by biologists and chemists. Often somebody coming fresh to a subject from the outside sees something that those already working on it have missed. All kinds of special techniques may be applicable to the problem.

As an example of this last statement, here is an instance where radio has helped war surgery. One of the difficulties in surgery of this type is to detect and re-

move all the splinters and fragments which may have got into a wounded man; often they travel a considerable distance from their point of entry, and they are not at all easy to follow up. They can be seen, of course, if a general X-ray photo of the patient is taken. But that takes time, and the available X-ray apparatus is likely to be kept very busy on other jobs. A new device for tracing lumps of metal in the body has recently been introduced. A tuning coil, attached to a radio oscillator, is mounted in a thin porcelain tube. When this is brought near a particle of metal, the inductance of the coil changes, and alters the frequency of the oscillator. It is easy to arrange a circuit which enables one to detect this frequency change by the alteration in pitch of a note; and the surgeon can listen his way towards the buried bullet.

THE ELECTRON MICROSCOPE

E. M. CROOK

OF the tools used by the scientist, the most familiar to the layman are the test tube and the microscope. The white-coated figure peering into a microscope is probably what most people picture when told that Mr. X is a scientist. The interest and thrill of being able to explore the minute beyond the limits of the unaided eye is enhanced by the realisation of what those explorations have meant to the health and progress of Man. His search for knowledge, the means of controlling his environment, has led him to enquire into ever smaller details of existence, and made necessary a continual improvement of the means of making these details visible to the human eye.

The eye, wonderful as it is, is a comparatively crude optical instrument. Two factors limit its ability to see detail. The first of these is its inability to focus on objects which are too close. Everything appears to grow in size as it comes nearer, so that more and more detail is visible; but when it is nearer than ten to fourteen inches, the detail is again lost through the eye's inability to focus. This distance, at which the maximum amount of detail can be seen, is called the *least distance of distinct vision*. The second limitation arises from the cell structure of the retina—the light-sensitive layer at the back of the eyeball. If two points in an object, observed at the least distance of distinct vision, are less than $\frac{1}{10}$ millimetre (25 millimetres = 1 inch) apart, they appear as one, i.e. they are not *resolved*. A good magnifying glass will increase the apparent diameter of an object twenty times. Thus objects $\frac{1}{200}$ millimetre apart will appear to the eye to be $\frac{1}{10}$ millimetre apart, so that more detail can be seen; a fact which is well known to everyone.

If larger magnifications are necessary, a microscope must be used. The best modern instruments can magnify 1,000 to 1,500 diameters. Unfortunately, this does not mean that distances of $\frac{1}{10,000}$ millimetre can be resolved. Certain other limitations prevent this being so for distances less than about $\frac{1}{5,000}$ millimetre, and that is as far as we can hope to get with an ordinary type of microscope.

However, in 1937, the German physicist Ruska built an electron microscope which had a resolving power ten times as great as the best ordinary microscope. Just before the war it was possible to buy such an instrument from the Siemens Company, and the Radio Corporation of America now make one with a resolving power of $\frac{1}{200,000}$ millimetre and magnifications up to 25,000 diameters. Seven of these instruments have recently arrived in this country under the lease-lend arrangements. It is now manufactured by Metropolitan Vickers, in England.

But how do these various microscopes work and why do they have these limitations?

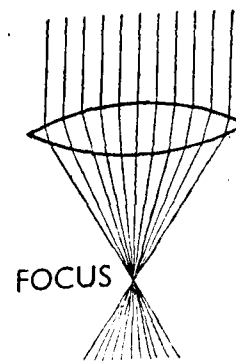


FIG. 18

LIGHT MICROSCOPES

Everyone is familiar with a burning glass and how it will bring the sun's rays to a focus. This is an example

runs through the whole subject; the answer may lie, as we shall shortly see, in the fact that every person's body proteins are slightly different, and characteristic, and therefore liable to react differently to the same chemical. But if this is so, it has yet to be proved, and is at present only at the stage of speculation. Sensitivity to hair-dye is perhaps of secondary importance, but a hyper-sensitivity to specific drugs is vital, because it may limit treatment so severely: it is liable, for instance, to arise during the use of sulphonamides (including the famous M. & B. 693) and cause a drug fever as the first sign, whereupon the drug has to be stopped at once and cannot be used again, unless the patient can be de-sensitised. Hypersensitivity has been known to occur to most of the drugs in the pharmacopœia, including even aspirin, but some are worse than others, and one, amidopyrine, has for this reason been dropped by medical science, though it is still commonly a constituent of headache powders produced by patent-medicine manufacturers, and its very serious effects, with a sore throat as an early sign, are still well known to doctors. It seems likely, too, that many industrial dermatoses—skin inflammations caused by chemicals used at work—may be allergic in nature.

Allergic reactions thus are a serious problem, and methods of de-sensitisation, and even more, of prevention, are highly desirable: to devise this treatment a thorough scientific investigation of the factors involved is needed. The first question that naturally arises is to what kinds of substances one may become allergic under natural conditions, and whether there is any common factor amongst them to explain the common reaction. The purification of natural allergens, whether from the primrose, from grass pollen, or from a food, leads in every case to the same answer—it is a protein. Experiments on animals, the guinea-pig, for instance, in which an artificial hyper-sensitivity is easily produced, lead to the same conclusion. The injection of fats, or carbo-

If we want magnifications greater than 25, it is much more convenient to use two stages instead of one, i.e. to use a *compound* microscope (Fig. 20). Here, instead of looking directly at the object, we use another lens (O), now called the *objective*, to throw an enlarged picture of the object just inside the focus of our simple microscope (now called the *eyepiece* or *ocular*, E), at (P). The eyepiece then magnifies this image another stage in exactly the same way as our simple microscope magnified the real object. If the objective throws a picture

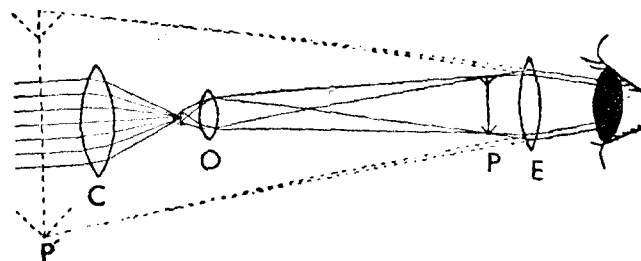


FIG. 20

ten times the original in size and the eyepiece magnifies this another ten times, the total magnification will be one hundred.

In practice, of course, the objective and eyepiece are not single lenses as shown in the diagram, but combinations of several, making possible better images free from colour fringes and distortion.

It would seem that by having a number of stages, each magnifying the image from the one before, it should be possible to have almost limitless magnification. But several snags arise if this is attempted. First, there is trouble with light. As the image is magnified, the same amount of light is spread over a greater and greater area. Consequently it becomes dimmer and dimmer and soon is too faint to see. To light the object as brightly as possible needs an extra lens, the *condenser* (C, Fig. 20), to

of a simple lens and its action (Fig. 18). The distance from the lens to the point where the rays are focused is the *focal length*. If this lens is placed close to the eye it will bend the light rays coming from any object placed within the focal length in the way shown in Fig. 19. Then they appear to come from the enlarged object (dotted) instead of from the smaller real one. The shorter the focal length the greater is the magnification. However, as the object has to fall within the focal length for the lens to act in this way, too small a focal length

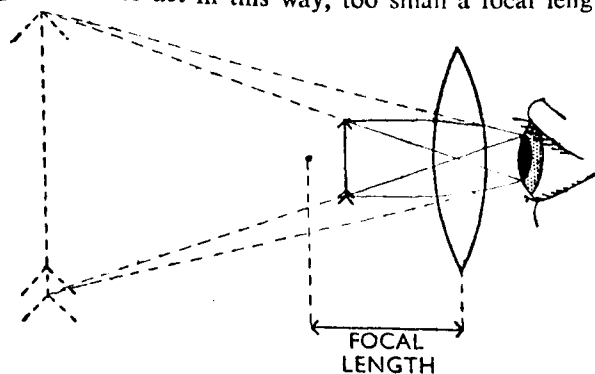


FIG. 19

cramps the working space and makes it very difficult to light the object. The practical working limit for such a *simple* microscope is a focal length of about 10 millimetres, giving a magnification of about 25 diameters (magnification = least distance of distinct vision divided by the focal length).

The great Dutch naturalist, Leeuwenhoek, who lived at the beginning of the seventeenth century, made himself a large number of simple microscopes. It is certain that he used magnifications much greater than 25, as many of the "little animals" he so beautifully described could not be seen at that magnification. But his microscopes must have been very difficult to use and extremely bad for his eyes.

can try to keep away from the things which upset him and precipitate attacks, pollen extracts and the various kinds of dusts can be pricked into the skin in the so-called "patch" test: only those to which he is hypersensitive will produce a little weal or blister—the rest, and almost anything else you like to prick in, produce no response whatsoever.

Perhaps the mucous membrane of the nose is in some way more permeable and lets the dust through, in those who get hay-fever. In asthma, on the other hand, there are very definite hereditary factors, of which temperament seems to be one. The allergic reaction, sudden contraction and constriction of the smooth muscle of the lungs means that one can breathe in, but not out, so that there is a bursting, choking feeling in the chest. Here again the precise causation is obscure, but the nervous system seems to have a rôle. A rarer, but well-known, type of allergy is that due to food. Some people are unable to eat strawberries, or duck eggs or crayfish, and some children cannot drink cow's milk (though the goat's is harmless) without coming out in a violent itching rash of "heat bumps" accompanied sometimes by a temperature and muscle pains. The explanation of this offered by doctors is that the mucous membrane of the intestine is unusually permeable, and lets a little of the undigested food through into the blood stream. With an uncommon food the time gap between the first meeting and the second occasion of eating is sufficient to allow a hyper-sensitivity to arise.

A most important group of allergies is that due to sensitivity to various synthetic chemical products. Every now and then a case is reported in the newspapers where somebody has used a hair-dye or worn a fur and come out in a violent rash, and is claiming compensation from the supplying firm. Many of these cases are due to an acquired sensitivity, but for some mysterious reason only very few people are ever affected by a given dye. In fact, the problem of idiosyncrasy

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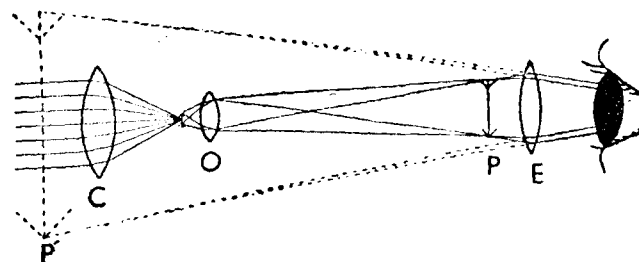


FIG. 20

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concentrate the light from the sun or a lamp on the object. Some light is lost at each lens, since no glass is perfectly transparent, and this too sets a practical limit to the number of stages that could be used.

However, neither of these is the most serious consideration. The real limit is the fact that magnifications much greater than 1,000 diameters are simply *no use*! No matter how perfect the lenses, or how bright the light, the optical microscope cannot resolve objects less than about $\frac{1}{10,000}$ millimetre! To magnify this to $\frac{1}{10}$ millimetre, the least distance the eye can resolve, needs a magnification of 500 diameters. The extra 500 or so is added to make sure that the eye is relieved of all strain and shown the detail easily.

Why this annoying limit?

LIMITS OF RESOLVING POWER

To answer this we must look more closely at how an image is formed. Light, as most people know, is a wave-motion, something like waves in the sea, but electro-magnetic in character. If a beam of light, consisting of these waves, falls on an object, the waves are stopped by the opaque parts, but travel through the transparent parts, are collected by the lens and projected as an image. If the opening between two opaque parts is less than the length of the light wave (the *wavelength*), the waves are broken up and scattered over a wide angle on the other side. This means that such spaces do not appear in the image, since very little of the light reaches the objective lens. In a similar manner, an opaque spot smaller than the wavelength of the light, and set in a transparent field, scarcely affects the light. The waves flow around it and it does not show in the image. Thus, detail smaller than the wavelength of light cannot be seen however great the magnification. Yellow light, to which the eye is most sensitive, has a wavelength of about $\frac{1}{5,000}$ millimetre, and hence this is the limit of resolution referred to above.

Ultra-violet light has a shorter wavelength than ordinary light. Hence its use increases the resolving power a little (about twice), but entails the use of quartz lenses because glass is opaque to ultra-violet. Apart from the expense, other difficulties are involved in its use, and very little progress has been made in this direction.

How then was this apparently insuperable difficulty overcome?

ELECTRON OPTICS

It has been known, since Einstein's work at the beginning of the century, that light waves and X-rays had many of the properties of minute particles. In 1926, the French physicist de Broglie suggested that electrons, the particles of negative electricity shot off by hot filaments, might also behave like waves. In 1927, Davisson and Germer in America, and G. P. Thompson in England, proved that this was indeed true. Thus, electrons are now known to have a dual character. As one English physicist has put it, they behave like waves on Mondays, Wednesdays, and Fridays, and as particles on Tuesdays, Thursdays and Saturdays. The wavelength of electron waves varies with the speed of the electron. The faster it goes, the shorter is the wavelength; but even when moving slowly, the wavelength is very small, about the same as X-rays, i.e. about $\frac{1}{10,000,000}$ millimetre. If we could control and use a beam of electrons as we would a light beam it should theoretically be possible to obtain a resolving power as great as this. But, electrons will not pass through glass. Indeed, even fast ones are stopped in a few inches by air! How, then are we to focus our beam?

To answer this, it must be remembered that electrons are negative charges, so that they are repelled by other negative charges and attracted by positive. Indeed, this is the means by which a beam is produced. In Fig. 21, electrons are given off by the hot filament F, escape through a hole in the casing C, and are attracted

toward the positively charged plate P, which also has a hole in it. As they go their speed rises because of the attractive force, and although many end up on P, the

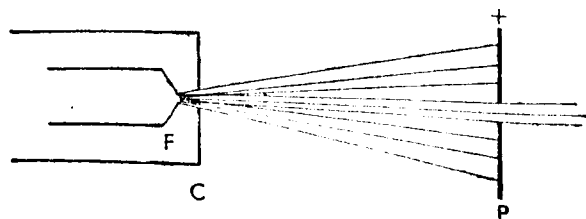


FIG. 21

remainder fly through the hole and emerge on the other side as a beam. If P is, say, 60,000 volts positive, the speed of the electrons in this beam is about 60 miles per second. The whole set-up is called an *electron gun*.

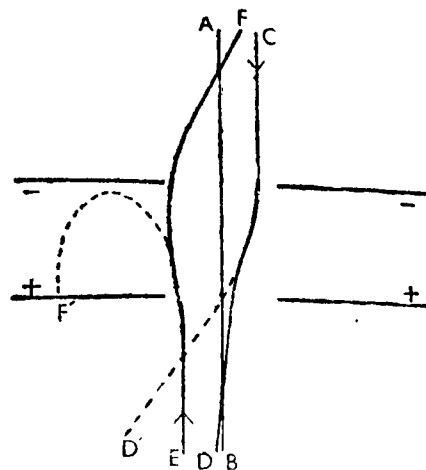


FIG. 22

Now let us look at the arrangement of charged plates shown in Fig. 22. It consists of two flat rings set one above the other. An electron moving along a path

A to B, passing through the centres of the two holes, will be repelled equally all round by the edge of the hole in the top plate, and attracted equally all round by the edge of the hole in the bottom plate, i.e. it will pass through without being deviated from its course. All that happens is that it experiences a force repelling from the top plate and attracting to the bottom plate. If it is moving downwards it will be accelerated, if moving up, decelerated. But for an electron moving near the edge of the hole, the situation is different. For instance, one moving downward from C is repelled more from the near edge of the hole than from the distant one, and is pushed over in the direction of D. When, however, it comes near the lower plate, it is attracted by that plate, and would be bent back almost to its original track except that it has now been accelerated downwards, just as the undeviated electron was. Thus it spends much less time near the positive plate and finally ends up moving in the direction of D'. A similar action occurs on an electron moving up from E, but this time the order is reversed. The nett effect in either case is that the electrons are bent until they cross, i.e. the two plates act on electrons in exactly the same way that a glass lens acts on light—they form an *electric lens*.

We can also build a *magnetic lens* (Fig. 23). This usually consists of a specially shaped circular pole-piece on which a coil of wire is wound. When current flows in the wire, the pole-piece becomes magnetised and a magnetic field forms in the gap as shown. Now, when an electron moves in a magnetic field, it is pushed at right-angles to the direction of the field. Thus, an electron moving from B will be pushed as shown by the arrows and it will finally move in the direction of C. Again the action is to focus the electrons. This time, however, the action is more complicated. Looking down from above, it is seen that the magnetic field runs out from above, the top of the pole-piece into the middle of the gap, i.e. the plan is radial. Thus, an electron at D, being

deflected at right-angles to the field, will be driven in a circle towards E. The result of the two motions is that the electrons *spiral* to a focus in a magnetic lens. Up to date, the magnetic lens has been found more convenient and most electron microscopes so far built use them.

Using these lenses and an electron gun as a source of

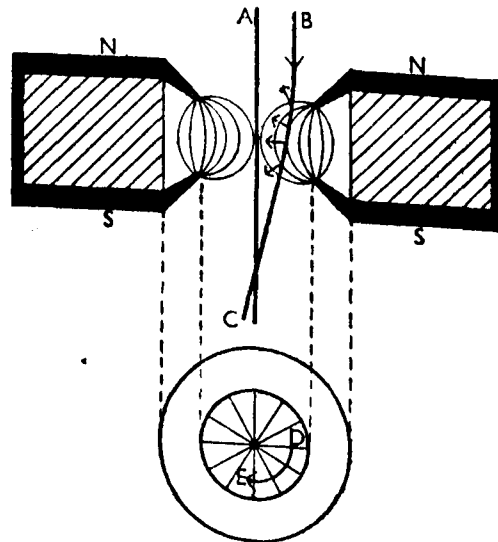


FIG. 23

electrons, we can build a microscope which is exactly similar in principle to a light microscope. For convenience, the high voltages are put at the top, so that the instrument is inverted when compared with an ordinary microscope (Fig. 24).

Two more difficulties are encountered by the builders and users of the electron microscope. The first of these is because, as we saw above, electrons are stopped even by air. Thus, the whole of the body of the microscope must be a very good vacuum. In the R.C.A. machine

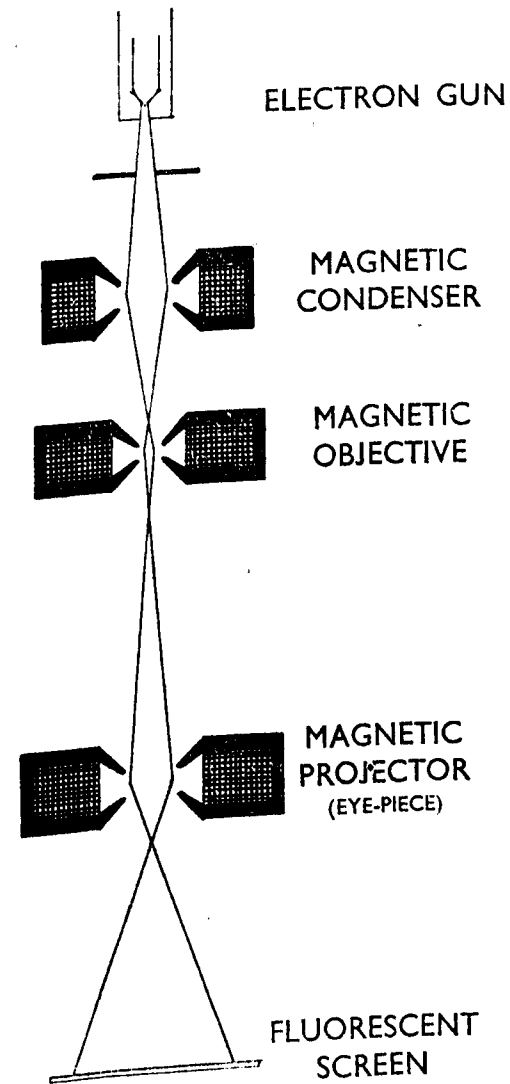


FIG. 24

two mechanical pumps and an oil pump are provided to ensure that as much as possible of the air inside is pumped out. Unfortunately water evaporates extremely rapidly in a vacuum, and so it is impossible to use anything wet as an object. More than that, electrons penetrate water only with difficulty and so do not form a good image of anything wet. It is rather like trying to see a clear glass marble in a bowl of treacle! This is one of the great drawbacks to the electron microscope at present, because many of the things such as bacteria and proteins, which scientists wish to examine with the new high magnifying powers at their disposal, are badly damaged by the thorough drying to which they have to be subjected in order to view them.

The other difficulty arises because electrons are not able to produce a picture on the retina, i.e. the image cannot be seen directly. However, by projecting it on a fluorescent screen similar to that in a television receiver it becomes easy to see. Alternatively, since electrons affect a photographic film, the image can be photographed.

THE R.C.A. MICROSCOPE

These features are embodied in the seven R.C.A. microscopes now in this country. Plate 8 is a photograph of the instrument, which stands about seven feet six inches high. The microscope proper is the tubular portion in the front. The base houses the oil pump for producing a good vacuum. The air is pumped out through the pipe running down between the microscope and the control panel. Behind the control panel are fifty-three radio valves used for producing the high voltage for the electron gun and for regulating the current in the magnetic lenses. This has to stay very constant to keep the object in focus, because the amount of bending of the electron path depends on the strength of the magnetic field, which in turn depends on the strength of the current in the lens-coil. This also allows

us to alter the focus by altering the current in the coil. The amount of bending of the electron path also depends on the speed of the electrons, fast ones being bent less than slow ones since they remain in the field for a shorter time. To keep the object in focus it is thus necessary to regulate carefully the high voltage in the electron gun, since it is this which determines the speed.

The high voltage connections are in the top. Immediately below this, are a set of screws for centering and positioning the electron gun, and below this, the condenser lens-coil. Next comes the specimen chamber out of which project two wheels for moving the mechanical stage which holds the specimen to be examined. The stage is used to move the specimen so that different parts of it can be looked at.

Between these wheels is a third for opening and shutting the specimen chamber air-lock. It takes a fairly long time—about 15 to 20 minutes—to pump out the whole microscope. For this reason, when a specimen is inserted, it is put in through an air-lock, the outer door of which (on the far side in the photograph) is closed and the chamber pumped out with an auxiliary pump before the lock is opened to the rest of the microscope. A similar lock is provided for putting in the photographic plate. The door to this projects from the left side of the machine and can be seen clearly.

Just below the specimen chamber is the objective lens-coil, and below this again the slanting viewing tube for looking at the intermediate image which falls on a small fluorescent screen. In an ordinary microscope no provision is made for seeing the intermediate size image, but here the magnifications are so great that there is some advantage in being able to see a less magnified image as well as the final highly magnified one. This image is then magnified by the "eye-piece" lens and the final image projected on to the fluorescent screen in the bottom of the bulging chamber at the base of the microscope. The port-holes all round this chamber are

for observing the screen. The screen can be moved out of the way when it is desired to take a photograph.

USES

The great stir which the electron microscope has made in scientific circles is due to its ability to resolve very minute distances. Theoretically, it should be possible to resolve objects $\frac{1}{10,000,000}$ millimetre apart. This is about the size of most atoms, so that at first sight it seems possible that the ultimate structural particles of matter should be seen. However, the magnetic and electric lenses at present available are comparatively crude. Comparatively, they are not much better than were Leeuwenhoek's lenses in the early history of light microscopes. Whereas the light microscope has now reached such a state of perfection that the light itself is the limiting factor, the electron microscope is limited by the distortions which arise in the lenses. These limit the resolution to about $\frac{1}{500,000}$ millimetres, so that the *useful magnification*, explained above, is about 20,000 diameters. Even this, however, is about 40 times as good as a light microscope, so that we can see such things as viruses and bacteriophage which are quite invisible under the ordinary microscope.

For example, Plate 9 is a photograph of the virus causing the mosaic disease of tobacco plants. It consists of rods about $\frac{1}{65,000}$ millimetre wide and of varying length. These are obviously beyond the power of an ordinary microscope, but give quite good pictures with the new instrument. There is some evidence that these particles are giant molecules of a certain kind of protein (*nucleoprotein*). Here, then, we are seeing for the first time, if not atoms, at least the larger building blocks of which matter is composed; and the limits are rapidly being reduced as technique improves.

In the same way, it has been possible for the first time to see something of the structure of finely divided pigments such as carbon black. It has been known for a

long time that the properties of these depend greatly on how they are made and what size the particles are. As these are very small, it has not hitherto been possible to see them. In order to measure their size it has been necessary to rely on various indirect methods the results of which are very difficult to interpret with certainty. Now that they can be seen and photographed the size can easily be measured directly. The information thus obtained is of very great value in making inks and paints, and, even more important, in knowing what its performance will be when carbon black is incorporated in the rubber for making motor tyres.

It is possible to take photographs of colloid particles such as colloidal gold. Here the metal is so finely divided that it remains permanently dispersed in water in particles too small to be seen by light. Other fine particles which have been studied are clays and the minerals composing them. It has thus been shown that many clay minerals which were formerly thought to be regular grains are in reality aggregates of long fibrous particles.

One of the most recent studies with the electron microscope has been of the structure of the wings of butterflies and beetles. The colours in these, although sometimes due to pigments, often arise from a structure too small to be resolved by a light microscope. The beetle's wings are a simple structure—parallel ridges and furrows, about 25,000 to the inch. These break up a beam of light into the colours of the rainbow, but do not show much in diffuse light. The scales of the butterfly's wing are more complex. They also have ridges, but on each are sets of vanes, each of which in turn has sets of horizontal thickenings all the way up, forming an almost cellular structure. Such a structure behaves toward light rather as an oil film on water does, i.e., certain colours are selectively reflected. This occurs if the distance between thickenings is half the wavelength of the light to be reflected. These reflections occur even

in diffuse light; which accounts for the "permanent" colour of the butterfly wing.

The very fine detail of the surface of metals can be well seen in electron micrographs. Because electrons will not go through metal a different technique has to be used. A thin film of collodion is spread over the surface and then stripped off. In this way a cast or replica is obtained and is transparent enough to be examined in the electron microscope.

Other things which have been studied include cotton fibres, soap curds, and the structure of catalysts. It has also been possible for the first time to see the action of light and of developers on a photographic film. During development, threads of metallic silver grow out from the exposed silver bromide crystals. When the excess silver bromide is dissolved away by the fixing solution, bundles of these threads are left to form the picture.

Enough has now been said to give some idea of the range and usefulness of the new instrument: Plates 9 to 15 illustrate the results; 9 and 10 were taken by Dr. F. M. L. Sheffield at Rothamsted Experimental Station with the microscope shown in Plate 8. They are included by courtesy of the Director of the Station. 11 to 15 were prepared in the Metallurgy Department of the National Physical Laboratory and are included by courtesy of the Director of that laboratory. Rothamsted and Crown copyrights are reserved.

CHEMICAL FRONT

THE USE OF SEAWEED

WAR always stimulates an interest in natural resources, and one of the most important aspects of this is the study of plants. The U.S.S.R., the United States, and Sweden, are now experimenting with the Russian dandelion, *Taraxacum koksaghyz*, because the sap in its roots yields 1-2 per cent of rubber. At this level it is not worth while growing the dandelion, but a study of the food the plant requires, the factors affecting the production of cortex, and the breeding of fresh varieties and cross-breeds of plant may lead to a variety which is an economic proposition.

A particular botanical field which has been little explored for use is that of the seaweeds. It is true that a certain amount of potash and of iodine has been made by the burning of seaweed, but real industrial uses are still to be found. When fresh brown seaweeds are boiled with washing soda solution, a gummy substance, Algin, is extracted. This can be treated in various ways; if it is vulcanised like rubber with carbon tetrachloride, it gives a hard rubbery solid which has been made into rollers for typewriters. If it is shaken up with a little tannic acid in alkaline solution, it emulsifies to form a transparent flexible plastic, which can be made into sheets very like "Cellophane," and used as a cheap, non-inflammable wrapping. By other patented methods it can be spun into threads, and the Japanese have made an artificial wool in this way from gulfweed (*Sargassum* species). Professor Speakman at Leeds has also developed a kind of rayon from seaweed which promises to be very important in the textile industry. Algin itself easily forms fibres, but these dissolve in soapy water and in alkali; but by treatment with metal salts (calcium,

chromium) they can be made stable to washing, and can be dyed too, all the practical details having been worked out in Speakman's laboratory during the war. Algin has also been used to keep powdered milk dissolved and free from insoluble bits, and similarly to keep the carbonate of hard water in solution and so prevent the "furring" of boilers.

Very little is known about the food value of seaweeds. Carrageen moss is useful for making jellies, though it is doubtful whether its carbohydrate can be digested by human stomachs. A number of plants (laver, dulse, murlins) are used as vegetables along the Scotch and Irish coasts, and the famous "Bird's Nest" soup of China is, of course, compounded of seaweed; pink laver is grown commercially in Japan for the same purpose. In the Orkneys, too, sheep are turned loose to graze at low tide on the coastal seaweeds, and calves have been fed on certain plants boiled with oatmeal. In the First World War a certain number of horses in France were supplied with seaweed as fodder. There seems to be agreement amongst agriculturalists that seaweed is quite generally useful as a supplement to otherwise poor feeds, and it is so used in some parts.

All the same, such knowledge as we have is largely empirical, and a proper survey of coastal seaweeds and their chemistry and food value is indicated. The sea is fertile ground which up to now has been allowed to run to seed. If Science takes a hand, it may come to be a new source of food and raw materials. Quite recently experiments were done showing that fertiliser could be added with good effects to the waters of sheltered bays just as it can to the soil: in this case the yield of fish per acre of sea-water was considerably increased—because the nitrate improved the growth of the small sea plants on which the fish depend for their food.

As regards our lakes Science has already begun to take a hand, a much-needed one at that. A hundred years ago or so, Lake Windermere and many other English

lakes were full of brown trout and char, which gave rise to a prosperous fishing and sporting industry; but as the lake has gradually silted up, and the water become enriched by the influx of sewage, which acts as manure, these valuable fish have been largely driven out and replaced by perch and pike. The perch, in fact, have multiplied so much that they never grow very large, but remain as shoals of little fellows which were, until recently, just an unmitigated nuisance for which no use had been found.

At the laboratories of the Freshwater Biological Association at Wray Castle on the shore of Lake Windermere, the director, Dr. Worthington, has been trying to find some way of dealing with the perch, and by studying their habits in greater detail than hitherto has been able to make a success of the problem. He finds that for some months in the summer the perch swim into the shallower parts of the lake, and while in those regions they are easily trapped. It is only necessary to put down a wire-netting trap, without any bait, and taking it up two days later, catches of as many as 500 fish may be made. The fish are tiny, about one ounce each in weight; but there are so many of them that the catch per trap averaged about 8½ lb. per night. Moreover, the fish can be used. British Fish Canneries, Ltd., are putting them up in tins like pilchards, and marketing them as "Perchines (Lakeland Perch)."

LIGNIN AND PLASTICS

The American Magazine *Time*, whose scientific reporting is on a level that very few English papers reach, recently drew attention to another industrial waste of a plant product which the stress of war has now brought to good use. Lignin is the hard substance which toughens the wood of old trees. It has to be removed from wood pulp in the manufacture of paper; and as it makes up a quarter of the original weight of the wood, there is plenty of it—in the United States and Canada about 3,000,000 tons a year.

Until the war it was simply a nuisance. A little of it could be profitably turned into vanilla essence, but even the American passion for ice-cream could not dispose of 3,000,000 tons of vanilla flavouring. But it has now been found possible to use it as a basis for making plastics. It is particularly suitable for laminated products, in which thin sheets of wood or cloth are glued together, under pressure, with lignin-derived glues—and then used for aeroplane bodies, etc. Moreover, lignin powders can be used to dilute other more orthodox plastics, and even synthetic rubbers, which as a result of the loss of Malaya and the East Indies to the Japanese, have become of prime importance to the Allies. It is fortunate that we already know something of the nature of these plant products, so that we have guidance as to how to reproduce them synthetically. So far Germany has done more work on them than any other country, since her rubber supply has always been insecure. But some of the artificial compounds are actually better than natural rubber in resistance to sunlight, oil, etc., and they have, therefore, been worth developing for their own sake.

The constitution of rubber is complicated and not fully understood, but the essential bricks of which it is built up are fairly simple. The basic unit is a group of four atoms of carbon, held together in a row; some hydrogen atoms are always attached to these carbons, and in some of the rubbers there are extra carbon-hydrogen groups stuck on at the side, but it is the simple row of four carbons that gives rubber its peculiar and valuable properties. The important thing about this group of carbon atoms is that its two ends are "sticky"; that means that a whole series of the groups can join together, like the links forming a long chain. In fact, in normal rubber, the links are always joined up in chains of many hundreds. These chains may be as much as a millimetre long; that does not sound much, perhaps, but when one is dealing with things as minute as atoms, it is a very long chain indeed.

One of the most important things about rubber is its stretchiness or elasticity. That depends on two things. Firstly, the chains are normally not straight, but coiled up in some sort of a spiral like a spring—chemists are still arguing about its exact shape. And secondly, the chains run in all directions, making a felted mass which has quite a lot of give.

It is fairly easy to get hold of the basic bricks out of which rubber is made; they can be prepared from crude oil, coal or even wood. The whole trick is to get the sticky ends to join up into chains of the right length, with the right amount of coiling. The process of joining up the links into a chain is known as "polymerisation," and it is a pretty mysterious business. The Germans originally did it by treating the raw, unjoined-up material with sodium. This gave the famous *Buna* rubber; the name *Buna* comes from butadiene, the name of the unpolymerised raw material, and Na, the usual chemical symbol for the sodium which was used as a polymerising agent.

Most of the better synthetic rubbers are still made on the *Buna* principle. The main improvements have been new tricks in the polymerising process. There is an American process, for instance, in which the crude butadiene is first made into an emulsion with soapy water, and then seems to give a better chain formation, for some reason which is not very clear. Again, various other substances can be mixed with the butadiene, with good results. But most of these refinements are secret.

There are some useful rubber substitutes in which the chains are built up of quite different links. In natural rubber, there is one extra carbon atom stuck on at the side of the basic group of four—the Germans used to make a most unsatisfactory "methyl" rubber which had two, and some of the newer artificials have none, while the American firm of Du Pont make a rubber which has a chlorine atom instead of the extra carbon.

But some of the substitutes are even less like the real thing. Thiokol, used for coating barrage balloons in America, has a link of two carbon atoms and two sulphurs. Koroseal, with a link only two carbons long, is used for transparent macintoshes. It seems, in fact, that satisfactory rubber substitutes can be built up from a lot of different links; the most important points are that the links must be able to join together into chains, but the chains must not stick together sideways—at least not too tightly, for that would make the whole mass into a firm solid like a plastic such as Bakelite.

So far synthetic rubber has always been more expensive than the natural product, but that is largely because it has been manufactured on a small scale. The enormous expansion in output planned in America should bring the costs down to a figure which may make it difficult for planters to compete. That may be one of the numerous technical revolutions which this war has brought about, and which are going to make the new peace quite different to the last.

PETROL IS NOW TOO GOOD

Oil chemists have beaten the plane designers; they can make a fuel which is too powerful for any present-day engine to use. The main problem in improving petrol is to get it to burn evenly in the cylinder, with a flame which spreads smoothly from one side to the other; if a secondary flame starts, the piston moves jerkily and minor explosions or "knocks" occur, and power falls off. The reason these secondary flames are so likely to occur is that the burning of petrol is actually a complex reaction in which petrol molecules combine with oxygen in a series of stages. The intermediate compounds of the "chain reaction," as the whole burning is called, exist only for the merest fraction of a second, but some of them have high energy, and if they meet an unchanged petrol molecule in the course of their short life they may start it oxidising too, which

means a second chain reaction running alongside the first. The intermediates of this too may induce further chains to start, so that though the burning of the petrol begins slowly, the longer it goes on the faster it gets: for it begins with only a few chains which rapidly bud off in all directions, until there are hundreds and thousands of them, with a grand crescendo, or explosion, as all the petrol suddenly finishes by burning at once.

So the aim in trying for smooth, regular, constant-speed burning is to stop all these side chains being started; and that can be done by a number of substances, but particularly metals, which collide with certain intermediates in the chain, pick up their high energy, and so prevent its further transmission and thereby end or abort the chain process. Until a short time ago tetraethyl lead was the favourite dope used for chain-breaking or "anti-knock," but more efficient dopes, the alkylates, are now available. These are made from metals and the natural gas that comes out of oil-wells or is produced in petrol refineries.

Modern aero engines can stand a fuel of "100-octane" anti-knock rating (octane is merely a substance the burning of which is taken for convenience as a standard—as the length of the human foot as a standard of length). America can easily turn out "110-octane," but Germany, with little natural gas at her disposal, had difficulty in getting her fuel above "90-octane," as analyses made by our chemists on captured enemy petrol have shown. This was unfortunate for the Germans, because the same engine will have a higher "full-throttle" performance, and a longer cruising range, if fed with the higher octane petrol.

The jet-plane, in which the burning petrol does not drive a propellor but produces volumes of rapidly expanding gas which blow backwards and so drive the plane forwards rather as a rocket works, is clearly in a rather different category from the ordinary aeroplane. The ideal fuel will be different from that commonly

used, and research will be needed to attain the best conditions—but at present it is all secret.

AND MINERS ARE UNNECESSARY

It is actually theoretically possible to run an internal-combustion engine on coal dust instead of oil fuel. There are, as would be expected, many practical difficulties involved, and in England there has been little attempt to develop a satisfactory model, but it is known that the ingenious German, ever on the look-out for substitutes for petrol, has been experimenting along these lines. According to Professor S. J. Davies, an engine something like a Diesel motor is being tested, but still suffers from many faults, such as wear on the cylinders and valves, breakage of piston rings, etc.

For most purposes, however, it is quite unnecessary to have coal in the ordinary solid form; gas does just as well or better. Why, then, should men have to undertake the dangerous and arduous labour of digging the coal out of the ground and carting it to the coke-ovens? Why not use the mine itself as a coke-oven? The suggestion was made many years ago by Mendeleev in Russia and Sir William Ramsay in England. It is only in the former country that it has been followed up. There are now several mines in the Moscow region where no men descend the shaft and no women wait with half an ear open for the hooter announcing an explosion. Instead, hot air and steam are pumped into one shaft, react with the coal at the bottom, and come up an outflow shaft as combustible gas, which can be piped into containers.

"Technological unemployment in peacetime?" you may ask; and it is perfectly true that very few people would be needed to get our fuel by such a system. But must we reject it on those grounds? Are we willing to admit that we must condemn men to grubbing about with a pickaxe thousands of feet underground simply because we cannot think of anything better for them to do if they stayed on the surface?

NEW TRICKS WITH METALS

Metals are another raw material in the handling of which there is still room for development, in spite of man's long acquaintance with them. It is only in the last fifty years or so, and especially under the stimulus of war, which demands steel for armour-plating for instance, that great strides in understanding and therefore in practice have come. Many of the most recent advances are recent because of their importance for war production, and America has released a good deal of information about her industrial practice; though similar advances have been made in this country, industrialists are more secretive about them. Nearly all high-grade steels include some manganese, say about 13 lb. per ton. Manganese itself is a brittle, rather useless metal, but when alloyed in steel it has the useful property of combining with the last traces of sulphur, impurities, making little lumps of manganese sulphide and preventing the formation of iron sulphide, the presence of which makes steel brittle. The United States has plenty of manganese ore, but it is mostly of a low grade which was impossible to work; the production in one recent year was only 100,000 tons, about 10 per cent of the requirements. Recently the United States Bureau of Mines discovered how to concentrate the common oxide ore. It is ground, and mixed with a "frother"—that is to say, with a substance, rather like soap, which in water produces a great froth of bubbles to which the ore particles, but not the unwanted rock, adhere. Then on stirring the mixture in water, the ore is floated off while the rock sinks to the bottom. The last step is to get the pure manganese out of the oxide ore. This is now being done with the cheap electricity generated at the Great Boulder Dam in Nevada, where the ore happens to be handy; a current is passed through a solution of the oxide ore, and, by the well-known process of electrolysis, the pure metal accumulates at the negative pole and oxygen is

process is being employed for various parts of automobile engines in the United States; small parts so far, as the pressures needed are very large, but bigger presses are being made, and the use of "powder metallurgy" is likely to grow.

Finally, a word about alloys—mixtures of metals, of which bronze was the first to be discovered by man. A team of research metallurgists in Ohio have recently described an ingenious new method of making alloys from metals which do not mix properly when melted, and which therefore cannot be alloyed in the usual way, by melting them together and then letting the mixture cool.

For instance, aluminium and lead do not dissolve in each other when melted; and no matter how thoroughly the mixture is stirred, nearly all the lead collects at the bottom as it cools, with the aluminium at the top. However, aluminium and tin do mix, and on cooling, the aluminium, with the higher melting point, solidifies first to give an interlaced network of fine crystals, and then the tin solidifies in all the fine interstices, so that a uniform alloy is formed.

In the new method of getting an aluminium-lead alloy, the aluminium-tin alloy is first formed. It is then kept at a temperature which melts the tin but not the aluminium; molten lead is poured on top and, being much heavier than tin, gradually seeps through the alloys and pushes out the tin. The tin is removed from the bottom of the crucible, and an aluminium-lead alloy is left to set, with exactly the same structure as the aluminium-tin alloy from which it was formed.

The method has been employed not only for metals which do not mix at all, but also for those which mix rather badly. For instance, a copper-tin alloy of high tin content (a so-called "White Bronze") is very difficult to make, but by first preparing a copper-bismuth alloy, and then replacing the bismuth by tin, a very good white bronze can be simply produced.

DAYLIGHT UNLIMITED

A great deal of war production involves accurate, eye-straining work; and in factories working all round the clock, adequate lighting is one of the first essentials. The recent development of fluorescent lighting has given it many advantages for such purposes, and its use is increasing rapidly.

The scientific principles on which fluorescent lighting acts are still unfamiliar to many people. It is a two-stage process. The first stage is the production of an electric arc through an atmosphere of mercury vapour under low pressure. Arcs of high voltage, working through mercury or sodium vapour at high pressures, are very efficient sources of light, but the colour of the light they give is unpleasant for continuous use; similarly, the arcs running through low pressures of gases such as neon give light which is not suitable for general illumination. The low pressure mercury vapour arc, which is the first stage in the fluorescent lighting, is in some ways even less satisfactory and produces visible light with very low efficiency. However, it also gives out a considerable intensity of ultra-violet radiation; and although this cannot be seen, it is capable of producing all kinds of striking effects, as anyone knows who has had his skin burnt by the ultra-violet rays of the sun. One of the things ultra-violet can do is to cause certain substances to become luminous and emit visible light. That is the second stage in fluorescent lighting. The tube containing the mercury vapour arc is coated with a fluorescent powder which is stimulated to become luminous by the ultra-violet rays which fall on it.

This rather elaborate process has several very important advantages. Firstly, there are quite a large number of fluorescent powders available, and by mixing them in suitable proportions one can obtain light of any desired colour. In particular, one can make very good imitation daylight; in practice it seems to be found that true daylight-colour is only satisfactory at high intensities,

being rather depressing at low levels; when something a little "warmer" has a more cheerful effect. Secondly, the light is not emitted from a small area, such as the hot wire of an ordinary tungsten bulb; it comes out evenly from the whole surface of a large tube. There is therefore much less glare, and the shadows are not so sharp. Finally, one can provide a bright illumination without making everything too hot; for equal intensities of light, fluorescent lamps give only a quarter as much heat as tungsten lamps—a very important advantage in blacked-out factories.

ALLERGY

JOHN ENOGAT

A FEW years ago a curious thing happened to a friend of mine. One evening his right hand and arm began to go red, and by the next day had become swollen and itched so badly that he had difficulty in getting to sleep that night. In the following days his condition gradually got worse: the swelling increased and spread slowly up his arm to the shoulder, and the chest and trunk became involved with a similar swelling. It was as if he had been stung by a huge stinging-nettle and the patch had slowly spread. His family were greatly puzzled by it, and so at first was the doctor, who went over his recent life to discover if anything had occurred which could account for the illness. It seemed possible he might have touched something with his right hand, and so started the trouble: the doctor had seen that sort of thing before. Now it so happened that the vicar had given him a pot of primroses, *Primula abconica*, the very day on which his hand began to swell, and they had been on his bedside table ever since, in full flower. Could this be the source of the trouble? A simple test soon showed that it was. A leaf off the plant was placed on one of the patient's legs for a few minutes, and about an hour later, long after its removal, a big weal came up in the skin in that place; both the doctor and my friend's wife also touched the plant but without ill-effect. After this experiment, the plant was removed from the sick room and burnt, and at once my friend became better, and in a few days was perfectly well again—the final proof that the primroses were responsible.

I know this sounds more like a tale of witchcraft and magic than sober scientific fact, as though the vicar had cursed the flowers to wreck my friend's health, so that

they were harmful only to him; but in truth the whole affair is only an example of a well-known phenomenon of hypersensitivity in which this particular variety of primrose, *Primula abconica*, is a notable offender. A single series of contacts with the plant is quite harmless, but after a time away from it, a second contact produces the most startling response in a proportion of people who have become hypersensitive to it: in my friend's case, he had grown the plant in his garden two years before, without ill effect, but inevitably getting plant material—a piece of crushed leaf perhaps, on his hands from time to time. There is nothing poisonous in this—in itself the plant is perfectly harmless; but it is unfortunately particularly potent in producing a state of hypersensitivity to itself, so that a second meeting with the harmless material is a serious matter, as my friend found to his cost. In such circumstances the only thing to do is to keep away from the plant for evermore, because the hyper-reactive state persists for a very long time.

The phenomenon of Allergy, of which this is a good example, is the development of an abnormal reaction to something, which normally means a hyper-sensitivity, inherited or naturally or artificially acquired. The symptoms vary somewhat according to the way the excitant arrives; there may be rashes (urticaria), running of the nose and watering of the eyes as in hay fever, paroxysms of inability to breathe out as in asthma, and less commonly fever, and pains in the muscles of the back and legs. Mention of hay-fever reminds us of what is probably the commonest allergic illness, particularly prevalent in the spring and summer months when pollen of various flowering grasses is inhaled; why some people become hyper-sensitive to the pollen is not known, but anyway they do, with consequences that we all know. Sometimes not pollen but hair fragments from a cat or dog, or dust of one sort or another is the excitant, or allergen. So that the sufferer

hydrates such as starch, is quite harmless, and the same is true of salts and vitamins and a vast range of organic compounds, but proteins almost invariably produce a response.

This might seem to contradict the fact of allergic response to drugs, but there are indications that this, too, is basically a protein reaction. Everybody's blood contains protein circulating in it, and this protein, of course, being one's own, produces no reaction of any sort, when removed and then re-injected. But it is possible by simple chemical reactions to make dyes combine with the blood protein outside the body, and this seems to change it, so that now on re-injection it behaves as if it were a true foreign protein since it can now produce hyper-sensitive reactions, the body's reply to foreign protein. It seems possible that drugs administered may, once they get into the circulation, under certain circumstances, combine with the protein of their own accord, and so set the stage for allergy.

The fortunate fact that artificial sensitisation is possible in the laboratory animal enables us to analyse the whole process with confidence, now that we are aware of the kind of causative agent. Let us do an experiment together which illustrates the whole thing. We take four guinea-pigs from the same litter and inject two of them with a protein, say a little white of egg dissolved in water. Then we keep the four animals on the same diet in the same hutch under the same conditions for ten days to a fortnight; they are all perfectly well, and the two which had the injection appear no different from the other two. However, if we now give one of them a second injection of egg-white it will show a strong allergic (or anaphylactic) reaction, with asthma, convulsions, and death, whereas one of the untreated animals now getting a dose for the first time is quite unharmed. Post-mortem examination shows us that the dead guinea-pig has generalised symptoms of shock, and that smooth muscle everywhere, including the blood vessels, is

affected, suggesting that the circulation plays a part. So we take guinea-pig 3 (injected fourteen days ago) and transfuse some of its blood into guinea-pig 4 (untreated). If we now also give animal 4 an injection of egg-white it will straightway show the allergic response: we have made it hypersensitive by the blood transfusion, and so demonstrated that the hyper-sensitivity can be transferred.

Experiments of this kind when pursued further show that the hypersensitivity to egg-white develops slowly over the period between the first injection and the second, and concurrently an "anti-protein" is developed by the animal in the blood. This is also a protein, which is capable of combining specifically and only with the allergen. The complex so formed outside the body in a test-tube has no particular action when injected; but when the allergen and its anti-body combine in the tissues of the living animal, a series of reactions go on which result in the liberation of a natural chemical substance called histamine, which has all the properties of a drug and is the actual immediate executor of the allergic reaction: histamine affects smooth muscle, and causes asthma, histamine pricked beneath the skin produces a typical nettle-rash weal. How and why histamine comes to be liberated is still one of the unsolved problems of science, and one under active investigation at the moment.

These effects produced experimentally in guinea-pigs have been found also in man. During the war of 1914-18, when tetanus toxin was injected into large numbers of men in the course of immunising them, it was found that if the second injection of the series was delayed too long, it produced a typical anaphylactic response when it finally came. Cases of serum sickness are also known where people have received a course of immunising injections against one germ, using a serum prepared from the horse (as is usually the case) which is unpurified and therefore contains unspecific horse

proteins. Years later they have been immunised and— an allergic response follows at once. This kind of thing is extremely rare now that we understand it better, but it does still occasionally happen. As in the case of the guinea-pig, the hypersensitivity can be transferred by blood transfusion. The story is recorded of a lady who received a blood transfusion from a groom and was henceforth unable to pass a horse without sneezing, while to lie on a horse-hair sofa was agony; and sensitivity to food allergens, strawberries for instance, has also been transferred in this way.

Usually this acquired sensitivity wears off after a time, which is fortunate, as, to be quite honest about it, there is no good method of desensitisation. Research has not yet advanced far enough—at least, that is the excuse we can make. There is one method, which theoretically ought to work, and that is the frequent injection of very minute amounts of the allergen in doses too small to produce noticeable or unpleasant reactions, but adequate to wear out the reaction mechanism. This ought to work, but for some reason the results are unsatisfactory. The only other treatment is symptomatic and applies chiefly to sufferers from asthma, and that is to use a drug which counteracts the effects of histamine, on the lungs in particular. A tablet of ephedrine, or an injection of adrenaline taken at the beginning of an asthmatic attack will prevent its development quite successfully. But the root cause of the allergic response remains untouched, and the only solution at present is to find out what the allergen is in a particular case and then for the patient to try to avoid it.

What is the use of this queer reaction? you may be tempted to ask, and the best answer seems to be that it is no use, but a sign of something seriously wrong, a sign of a foreign protein entering and upsetting the body. There is, however, another variety of allergic response which may have a value—the question is at the moment hotly debated—and that is a reaction to germs and their

products. If a guinea-pig or man has an injection of tubercle bacilli and manages to recover from it, a second group of invading tubercle bacilli will find it much harder to establish itself. In fact, if they are entering through a skin scratch, there will at once be a reaction in miniature around the invaders, and they will be cut off from the rest of the body in a little area of dead tissue, and finally allowed to drop away. The reaction remains local in this manner, and dissimilar to the anaphylactic reaction, because there is no circulatory anti-body, but after the first infection the tissues have become sensitised to the proteins of the tubercle bacillus (tuberculin) and when they meet it on the second occasion they react at once wherever they come into direct contact with it. But there is no histamine release, and therefore no generalised response.

This localised hypersensitivity response occurs not only in tuberculosis but in many other bacterial diseases, and may have a valuable part to play in the body's defence system, by casting out the first waves of invaders, though authorities are divided on its precise actual value. It has in addition a technical use in medicine because it enables us to test for previous infection and thus not only to discover precisely which people need artificial aids to their immunity to germs and which do not, but also to investigate how many people have had a disease in a sufficiently mild form not to have noticed it, and so to aid the study of epidemiology. The test is the "patch" one in which a drop of the appropriate extract is pricked under the skin, and the presence or absence of a local necrotic reaction noted.

One final aspect of Allergy deserves mention, though the picture here is much more vague and incomplete, little more than a speculation and an incentive to further research. This is a group of illnesses which are not accompanied by germ infection, but preceded by it. It seems that rheumatic fever, and kidney diseases, for instance, may be due to a hypersensitisation of some of

the body tissues to products of metabolism from the scarlet fever bacterium, which may grow in the throat and cause only a tonsillitis; but in a proportion of cases about three weeks after the illness is apparently over, blood and protein appear in the urine, indicating kidney damage, an indication which is confirmed if the kidney is examined under the microscope in a case that comes to post-mortem. It appears from the sequence of events that the first infection with scarlet fever sensitises the kidney cells to some of the germ's products, that then the infection clears up for a while, and then as often happens comes back again in milder form, whereupon the hypersensitive kidney cells react with the germ products and die. If this is so there are thus two kinds of allergic response: the better known type associated with the release of histamine which causes the symptoms, and this second type, which is not a reaction throughout the body, but confined to the killing of cells in a particular tissue, and in which no histamine is released. In the present state of medical knowledge it is possible to make many illnesses fall under one of these two groups—anything spasmodic is at least superficially allergic, and some doctors would consider epilepsy and migraine, as well as some kinds of heart palpitations, various skin and blood-vessel diseases, to be a hypersensitive response. The evidence, however, is slight, and it seems that we must await the physiologist's full working out of the reaction mechanisms in general terms before we can apply it specifically to medical practice, and in the meanwhile, as so often in medicine, we shall have to treat the symptoms of allergic disease rather than the disease itself. It must be admitted that since von Pirquet invented the word "Allergie" in 1902, its meaning has become better defined, but its fundamentals remain in much the same state of mystery.

PHYSICS OF THE ATMOSPHERE*

ERIC KRAUS

SOME years before the war a French engineer had a project to irrigate the Sahara, and to create a land of milk and honey—or rather dates and cotton—in an area which is at present waste and barren. The project was to dam up the Straits of Gibraltar, and thus to stop the flow of water from the Atlantic into the Mediterranean. The resulting difference of sea level could be used for the generation of power, which in turn would serve to pump water from the Mediterranean into the interior depression of the Sahara. The final result would have been the lowering of the Mediterranean by about 100 feet, and the creation of a large water surface south of the Atlas. It is assumed that with irrigation the soil of the Sahara is fertile enough to yield food in plenty. But what would have been the implications for the surrounding part of the world? Let us assume the project had been realised. Large masses of land would have risen out of the Mediterranean, the sea would have receded from the vicinity of valleys and plains, which are now subjected to its benevolent influence, and which would then have become as arid as are now some parts in the interior of Spain or the Balkans. On the other hand, the moisture which would accumulate in the air by the intense evaporation from the new inland sea of the Sahara would be carried south by the northerly winds which prevail in that region. We may then expect that the climate in the Sudanese steppes would become much wetter, and picture to ourselves a lush tropical vegetation flourishing there.

So far so good. But it occurs to one to ask whether the northerly trade winds in the southern half of the Sahara would still exist if the sand surface were replaced

*Written in 1943.

by water, and we see that the answer to the question what would happen if the Sahara were flooded is somewhat intricate. The branch of science which gives an answer to questions of that kind is called dynamic climatology, a term coined by the Swedish meteorologist Bergeron.

The old school of climatologists limited itself to a large extent to the statistical representation of a great number of observational facts. It could discover, while not attempting to explain, mysterious cycles as, for example, the curious fact that the growth of some trees follows a rhythm which is equal to an eleven years period of the sun-spot maxima, though we cannot observe a corresponding variation of the air temperature or humidity. These investigations were, however, mainly of a descriptive nature, and they were rightly considered to be part of our geographical knowledge. Dynamic climatologists, on the other hand, try to explain the climate, i.e. the general type of weather in different parts of the world and at different geological periods in a causal way, as a consequence of the physical events which accompany the transformation of solar heat into air motion. If we could know in every detail how this transformation occurred, we should also understand the mechanism which gives rise to the daily variation and vicissitudes of our weather.

The broad principles of the physics of the atmosphere are now understood, but a large part of our conception is still lacking in structural detail. The following paragraphs attempt to show on the one hand what progress has been made during the last twenty years towards an understanding of the actual mechanism, and, on the other, to reveal the biggest gaps in our present knowledge.

The atmosphere of the earth is a heat engine. When a fluid is heated at one place, and cooled at another, it will very often start to circulate. That this will happen can be easily explained with the aid of the diagram in Fig. 25. This figure represents a closed tube which is

completely filled by a fluid. Suppose this fluid is heated in the region A A, and cooled by the same amount in the region B B. Now, the cooled part of the fluid is heavier than the warm part. The fluid in the left branch will therefore sink towards the bottom of the tube, and another part of the liquid which has not yet been cooled will pass from above into the region B B. If the cooling in the left branch and the heating in the right branch persist, and if the "source" of cold B B is at a higher level than the "source" of heat A A, the fluid in the left side of the tube will be the whole time heavier than that on the right side. The whole content of the tube will be forced to circulate faster and faster in the direction

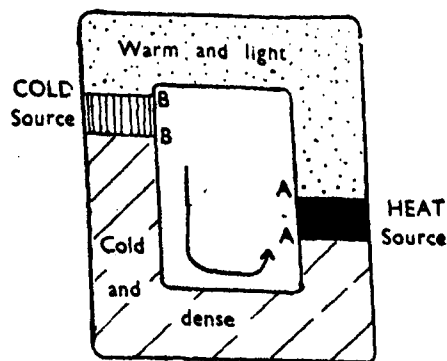
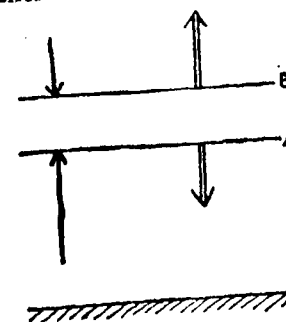


FIG. 25

of the arrow until the friction on the walls of the tube would prevent any further acceleration.

Exactly the same thing happens in the atmosphere. The air is heated at a low level above the surface of the earth. The principal heat sources can be found in the tropics and in the middle latitudes—over the continents during the summer, and over warm sea currents in winter. The main cold source does not lie, as you may expect, on the surface of the arctic ice, but can be found throughout the atmosphere at a higher level. In order to understand this we have to explain the principle of

the atmospheric radiation balance. All matter continuously emits radiant energy in all directions. The intensity of that radiation and the frequency of the oscillations increase with the temperature. The sun, which is a very hot body, mainly radiates high-frequency light waves towards the earth. These rays pass through the atmosphere without much interference, unless they strike a cloud, in which case they are generally reflected back towards space. Those parts of the solar radiation which do not suffer that fate heat the surface of the



Black arrows : Radiation absorbed by layer AB

White arrows : Radiation emitted

FIG. 26

earth. The surface of the earth transmits part of this incoming radiant energy upwards again. Because the surface of the earth is not as hot as the surface of the sun the outgoing radiation consists of rays which contain less energy, and have a lower frequency. When this low-frequency radiation strikes an object in its path it cannot be seen as light, but it may be felt as heat. Whilst the atmosphere is perfectly transparent to the short light waves, the heat waves cannot easily penetrate the light waves, the heat waves which is always found in the air. Consider an arbitrary horizontal layer of the atmosphere. The

water vapour in this layer will absorb heat radiation which comes partly from below, from the surface of the earth, and partly from layers above and below the one in question. It radiates heat both upwards and downwards at an intensity which depends on its own temperature. As we go upwards, we invariably come to a layer which loses more heat by radiation than it receives. This is represented schematically by Fig. 26. A layer of air which loses more heat than it receives is necessarily cooled. It is in that layer that we find the main cold sources of the atmospheric heat engine. The air is forced to sink in the regions where it is mainly cooled, and it must rise over heated areas, similar to the manner in which the fluid behaved in the tube represented by Fig. 25. Between the two it travels horizontally. All the winds, the motion of the clouds, the passing of cyclones and anticyclones are caused by the heating of the air at some places, and by its being cooled at other places. As the atmosphere as a whole gets neither hotter nor colder, the loss of heat on the one side must be exactly equal to the gain on the other side.

In order to understand fundamentally why a wind blows from a certain direction, with a certain speed, we would have to know the location and intensity of the heat and cold sources in the atmosphere. The complicated system of radiation and re-radiation in all directions in the atmosphere, and the unequal distribution of water vapour makes this a very difficult problem, which is far from having been solved. However, some years before the war, an admirable tool for further investigation was created, in the form of an atmospheric radiation chart. This is a complicated-looking diagram, on which the temperature and the moisture content at different levels overhead should be entered, in order to deduce the intensity of the upwards—and of the downwards—going beam of radiation at any chosen height. The chart was first constructed in Germany, but was later much improved by Dr. Elsasser in California. It may

have to be revised at a later date, when our present crude knowledge of the radiative properties of water vapour under atmospheric conditions is replaced by more refined measurements. The main snag which prevents us from making greater use of this radiation chart at the present moment is our inability to measure accurately the moisture content in the free atmosphere. The discovery of a device which would facilitate quick and precise measurement of the moisture in the air would take us a good distance along the path of atmospheric explorations. At the very moment it is probably exciting the brains of would-be inventors in many parts of the world.

The conception of the atmospheric circulation which we can form is further complicated by the extent of the "sources," and by the rotation of the earth. The deflecting influence of the earth's rotation on air and sea currents was well understood as early as the eighteenth century. The explanation of this subject does not fall within the scope of this article, since it has already been dealt with in many textbooks and popular treatises. All we need here is an indication of the wind systems generated in various latitudes by the heating near the equator and the cooling near the poles.

Near the equator itself, we usually find a zone of calm or light variable winds. These are the doldrums once dreaded by the crews of sailing ships which sometimes lay becalmed for weeks at a time. Adjoining the doldrums is a belt of prevailing easterly winds—the helpful trades. Round about 30° latitude we come to another zone without prevailing wind direction, and with frequent calms. This zone is characterised by almost eternally blue skies, and a very dry atmosphere. Most of the great deserts lie near this latitude. Beyond this zone again we come into a belt of westerlies, the strength of which increases the further we go towards the pole. Within this belt lie the roaring forties, that stormy zone of westerlies in which the grain ships sailed from

Australia to Cape Horn. Near 60° latitude the westerlies cease to be as predominant, and in the immediate vicinity of the poles we again find mainly easterly winds.

The predominance of winds from the east or west over those from north or south is a consequence of the deflecting force of the earth's rotation. It would be even more pronounced if the distribution of heat and cold sources were dependent only on the distance from the poles. As it is, this zonal distribution of the prevailing winds is more clearly realised in the southern hemisphere which is mainly sea-covered, than in the northern hemisphere where it is distorted by the influence of the great sprawling land masses.

But even if the heating and cooling were to occur in a perfectly symmetrical manner, i.e. if the earth were completely covered with water, zones of purely easterly motion and purely westerly motion could not persist; for if there were no southerly or northerly winds at all throughout such zones there could be no transport of cold air from the poles towards the equator, or of warm air towards the poles. The atmosphere would be cooled more and more in high latitudes, and it would become insufferably hot in the tropics. This we know is not true. At some stage, large eddies invariably develop in any purely westerly or purely easterly current. These eddies appear as vortices with a more or less vertical axis, and are called anticyclones when the rotation of the air is slower than that of the solid earth below, and cyclones when it is faster. Cyclones and anticyclones are the agents which carry out the meridional exchange of cold polar air masses with heated air from the tropics.

The cyclonic and anticyclonic eddies are a special feature of a large group of phenomena which are together described as atmospheric turbulence. We can study turbulence in any moving fluid. A stream may flow in calm majesty between gentle meadows, yet near the banks we can almost invariably observe small vortices and dimples which disturb the quiet surface. These

vortices in moving water have a much simpler construction than the atmospheric cyclones and anticyclones, though basically they are kindred phenomena, and if the exact laws were known which describe the motion of the former, we should not find it so difficult to indicate the behaviour of the latter. So far, turbulent motion has resisted all attempts to describe it by a coherent system of mathematical equations. The problem has been approached in two different ways according to the scale of the turbulence and the results which we wish to obtain. Obviously it is not very important for us to know the exact fate of a single smoke particle which comes, together with a multitude of other particles, from Mrs. Brown's chimney. Nor are we particularly interested in the exact movement of the air at any point in space which is associated with an individual gust of wind on the wide expanse of a storm-swept sea. What may interest us, however, is the pollution of the air which is due to the collective of all the smoke particles which are discharged during a given period of time from the chimneys of a city, or the transport of water vapour from the sea surface into the free atmosphere which is affected by the sum total of all the gusts. On the other hand, the air motion in an individual gust, which does not affect us particularly, will be very important to a small insect which has been caught in the whirl and carried high into the air. In relation to the large cyclones and anticyclones we are in a similar position. The size of man and his normal field of view is insignificant compared with these large atmospheric eddies, which will need hours or days to pass our villages and cities. In studying these phenomena we are not only interested in their statistical effect on, say, the transport of heat or moisture from the tropics to the arctic per year, but we are also vitally concerned with the structure of the individual eddy. For example, it is important for us to know that there is a south-westerly gale and rain during the morning

and a north-westerly breeze with good clearances in the afternoon. According to the question we ask we have to study in this case either a statistical collective of many eddies, or individual flow pattern of the air.

A complete statistical theory of turbulence which could be compared with the kinetic theory of gases, or with the quantum theory, has not yet been developed. Considerable progress has been made, however, in recent years, partly under the stimulus of aeronautical research, which is also vitally interested in atmospheric turbulence and its influence on the motion of aircraft. We are now in a position to compute approximately the evaporation from the surface of the sea or the drag of the earth surface on a wind. These are problems of small scale turbulence which were quite intractable only a few years ago. The effect of the large-scale turbulence which is represented by the collective of all the cyclones and anticyclones is also studied by many research workers, and we may expect that these studies will give us not only a better insight into the mechanism of the general atmospheric circulation, but that they will also form a basis for seasonal weather forecasts.

The investigation of the structure and the air flow in individual eddies received a strong stimulus some twenty-five years ago, when Norwegian scientists discovered that most of the cyclones in temperate latitudes form at the boundary between air currents of different speed and different density. This may be compared with the vortices which form at the boundary of still water and water which has been set in motion by the stroke of an oar. Owing to the centrifugal force of the rotating water, some of it is removed from the centre of the vortex, and a dimple will form on the originally undisturbed surface. In the atmosphere the removal of air from the interior of a cyclonic vortex whose velocity is increasing will cause a reduction of the weight of the atmosphere on the ground in the region of the centre. Hence we observe that the barometer will fall there, and

generally that low pressure coincides with cyclonic air flow. The boundary between two air currents is called a frontal surface; it is often fairly sharp, and the transition layer may measure only a couple of thousand feet, which is insignificant compared with the total height and extent of the atmosphere. The cyclones form initially as small wavelike deformations of a frontal surface, and grow into a more or less symmetrical vortex only at a relatively late stage of their life history. The finer details of this development are still largely conjectural and nobody has yet succeeded in representing it in mathematical terms.

The discovery of fronts and frontal cyclones was mainly based on observations from the surface of the earth. For the thorough exploration of a three-dimensional medium these are obviously insufficient. However, the last years before the war saw the creation of a very useful instrument for further practical investigation of the free atmosphere. This is the radio sonde which was invented almost simultaneously in several countries. It consists of a balloon which carries a set of meteorological instruments and a cheap automatic wireless transmitter. The development of a network of radio sonde stations permits us to measure over many parts of the globe at the same time the temperature, pressure and humidity, as well as the speed and direction of the wind up to a height of about 50,000 feet or more. Up to now the radio sonde observations have hardly given us any fundamentally new notion about the events in the upper atmosphere; interesting developments may be expected, however, when scientists have the time to sift thoroughly the data which were obtained by ascents during or just before the war. As mentioned above the humidity element of the radio sonde is also still much in need of further improvement.

Though our knowledge is still limited, and our technique crude, we know that a complete statistical theory of turbulence—once it has been developed—will be able

CURIOSITIES

THE MOST EXCITING EXPERIMENT IN THE WORLD

If you had a chance to do any experiment you pleased, unrestrained by any considerations of humanity or decency, what would you choose? It is difficult to think of anything which could be more important or more enlightening than to have a human baby brought up by a non-human foster-parents. There are apocryphal stories of such experiments actually being made by despots in the past. King James IV of Scotland is said to have isolated an infant on an island in the Firth of Forth, and to have discovered, some years later, that the child had spontaneously learnt to speak good Hebrew, the language of Adam and Eve. There are more authentic accounts of children who have been carried off and brought up by wild animals. The hormones in the blood of a female animal, when she is suckling, produce an enormously powerful "drive" towards maternal behaviour; a maternal rat will carry back almost any little furry object to her nest; and larger animals, wolves and bears, for instance, sometimes carry off human infants and care for them.

There are about sixteen or seventeen fairly authentic cases known of this phenomenon. Quite recently a new and very full account has become available of a case which occurred in India. A native Christian missionary, the Rev. J. A. L. Singh, rescued two children, who were named Kamala and Amala, from a wolf den in Bengal. Kamala was about eight years old when rescued, Amala only about one and a half. Both of them must have been adopted as quite young babies; presumably the mother wolf had a particularly active secretion of maternal hormones, and was twice driven to carry back to her den a man-child to take its place among the wolf-cubs.

The two children were taken by the good minister to the orphanage which he and his wife kept at Midnapore. Little Amala died within a year, but Kamala lived for nine years. The Singhs kept an elaborate diary of the long and slow process by which she was weaned of her wolf ways and brought back towards normal humanity; a short summary, with a few photographs, has been published by Dr. Arnold Gezell, of the Clinic of Child Development, New Haven.

Kamala seems to have been, by birth, a normal human child; but when she was rescued she was, by upbringing, a wolf. She ran on all-fours—on hands and knees for ordinary purposes, on hands and feet when she wanted to move fast, and then it was difficult to overtake her. She could not stand upright, the shape of her bones and muscles having been affected by her training in all-fours movement. During the day, she hid in a corner away from the light, squatting motionless for hours; at night she prowled around the courtyard and punctually at ten in the evening, at one and at three in the morning, she howled a peculiar wolfish cry. She lapped her drink, and ate without using her hands, and her sensitive nose enabled her to smell out and steal the entrails of fowls and other refuse from the rubbish bin. When the other children tried to make friends with her, she bared her teeth and snarled; only towards little Amala, her companion in the wolf-den, did she show any friendliness.

This is a terrifying picture of what can become of a human child of eight if it is deprived of all the social influences of a normal family and companions. But one must not misjudge Kamala. Her condition was not a mere degeneracy, a failure to become fully human; it was in some ways a remarkable achievement in becoming adapted to a wolf's existence. Her feeding methods were animal, but she was clean and left no scraps; she was "house-trained"; her rapid all-fours run must have taken some learning; and she had even copied her foster-mother in trembling her ears when

of letters in a single fixation whether the letters are printed very small or quite large. We move our eyes from one fixation to the next, not because we have seen everything within our field of view, but because our perceptive faculties have had enough of that position, and want a new one. So it is not unexpected to find that it is usually the brain which gets tired of reading before the eye muscles become fatigued.

THE FAT LADY

The death of Mrs. Ruth A. Pontico, of Tampa, Florida, was reported some while ago in the scientific press. This would be nothing for the world at large to take note of, were it not for her peculiar claim to medical fame as the fattest woman who has ever lived. Mrs. Pontico was a woman of only average height—5 feet 5½ inches—but her girth (76 inch waist and 91 inch hips) was something astounding, and suitable for one who on the day of her death at the age of thirty-seven, weighed over 55 stone. She began training for her career as professional freak at birth, when she weighed 16 lb. (the normal is 7 lb.), and by the end of her first year she weighed 4 stone—almost as much as some thin adults. In this she was only following her mother, who also was in the neighbourhood of 50 stone, but had a greater height to carry it off. Poor father, on the other hand, was a mere third of his wife's bulk.

We still know almost nothing of the cause of obesity. Food does not seem to be the primary factor: everybody has friends who remain fat in spite of dieting, or stay persistently thin while eating enormous meals, and Mrs. Pontico herself is said to have eaten only half as much again as a normal person. In her case there is clearly a hereditary tendency to bulk: presumably it found its way to expression through the only controls that have so far been discovered—the glands. But exercise also has a rôle: the more exercise one takes, the more food-stuff one burns up for energy, and therefore the thinner

one is likely to be on a given diet. Once one begins to get fat, however, one tends to be more sluggish and take less exercise and so get fatter, and so be still more sluggish and therefore fatter still and . . . so on. Mrs. Pontico used to walk up and downstairs and in her garden every day, but she took things very easily by normal standards, which was no doubt part of the secret of her "success."

But the whole thing is still a bit of a mystery. All recent work goes to show that fat is a thing one can have too much of in the diet. Excessive drinking harms the liver only if the alcoholic person has a fatty rather than a meaty diet, and the same is true if the threat to the liver comes from industrial poisons (T.N.T., for instance), rather than social ones. In the treatment of tuberculosis, patients are now being encouraged to eat twice the normal daily amount, but in starchy foods, not fat, and it is doing them good. It seems too that fat people may be more susceptible to illness than thin. Mrs. Pontico had pneumonia two years ago, and it took her a year to get over it, during which she lost 200 lb. in weight—which must have taken some while to get back again!

There is one new attack on the mystery of fat, which has thrown a new light on some of the most fundamental processes going on in our bodies. But the story begins in quite another science than medicine—in physics.

It has been known for some time that the atoms of any given element, such as hydrogen, need not be all alike in weight, although of course they must be all alike in their chemical properties (otherwise they would not be considered as belonging to the same element). The chemical properties of an atom depend on the number and arrangement of the electrons in its outer layers, while its weight depends on its nucleus, which lies in the centre and is so "covered up" by the outer layers that it scarcely affects the chemical behaviour, i.e. chemical behaviour and weight are really separable properties of an atom. The different forms of one and the same

There are two isotopes of hydrogen, the normal one with a weight of 1, and a much rarer one with a weight of 2. The second one, usually called "heavy hydrogen," sometimes Deuterium, occurs everywhere, for instance in ordinary water—but it normally makes up only a minute fraction of the whole. It can, however, be concentrated, and Professor Urey, of New York, has succeeded in getting fairly pure "heavy water," in which most of the hydrogen atoms have a weight of 2.

A New York biochemist, Rudolf Schönheimer, saw how to use this for a very enlightening biological experiment. By suitable chemical manipulations, he built the heavy hydrogen into the structure of various fats in place of the normal hydrogen they usually contained: this did not alter their *chemistry* in any way, but it did mean that he could always recognise those molecules again, as long as they hung on to their heavy isotope. He then took some rats and kept them on a diet which kept them plump and healthy but not gaining (or losing) weight. To these rats he gave some "heavy hydrogen fats," which, being chemically exactly like normal fats, tasted the same and had the same nutritive value. At various times after the meal, he killed a rat and analysed its organs to find where the heavy hydrogen had got to—normally the rat would contain only the usual minute traces of heavy hydrogen, so that any abnormally high concentrations would indicate what had happened to the heavy hydrogen it had eaten.

Schönheimer found that the heavy hydrogen appeared in the fat deposits in the rat's body within a very few hours after it had eaten. This is really most remarkable. It is plain commonsense to think of fat as the body's storehouse, where supplies of energy-producing materials are kept in reserve ready to be used if food runs out and the animal is in danger of starving. But Schönheimer's experiment shows that even these stores have a rapid turn-over. New fats are continually being laid down there, while the old ones are broken up and used to

produce the energy normally needed by the body. Other experiments were made with heavy nitrogen, since ordinary nitrogen is one of the component elements of muscle and other flesh. It was found that this heavy nitrogen very quickly gets built up into muscle and skin and organs. In other words these organs and tissues are not as permanent as they look, but must be in a continual state of tearing down and re-building. You may look the same person to-day as last week, and feel it too; nevertheless, you are not made up of the same atoms now as you were then. In fact it seems probable that the whole body is in a rapid condition of flux, ever-changing. Life is even more lively than it looks.

YOUR DEATH—AND MINE

When will you die? And what will you die from, because people rarely fade away from pure old age alone? Let's have a look at the Registrar-General's report on deaths in a typical recent six-monthly period, January to June, 1942, and see what other people died of during that time. No less than 13,317 people are recorded as dying of pneumonia, in spite of the introduction of the sulphonamides, including the famous M. & B. 693. The number of pneumonia deaths has been steadily declining in the last few years, but we still have a very long way to go in the treatment of this disease, before the doctor can really view it comfortably.

The lungs seem to be one of the weak organs of the human body, because tuberculosis (pulmonary) also accounted for no less than 11,828 deaths in six months. Here there is no drug and no real treatment other than giving rest and good food, and so helping the body to fight off the infection; and that works only if the disease is discovered early. The tubercle germ is unlike most bacteria in being wrapped in a thin protective coat of fat which prevents all the drugs so far discovered from getting inside and killing it. So it grows slowly and quietly, and the tissues around it die and become dense

and fatty, too, and as there is often no pain or bleeding, their presence can be detected only by the shadow the fatty mass casts on the film when the chest is photographed by X-rays. The Ministry of Health's plans for earlier diagnosis by mass radiography in this way should eventually show their value in a decrease in the annual death rate from tuberculosis.

Cancer, as might have been anticipated, was far and away the commonest cause of death in bed: there were eight deaths every hour, or a total of 35,240 people. When to this number of deaths is added the numbers who discovered they had it when it had not gone too far for surgical or irradiation treatment, and who consequently were cured, its importance as the commonest serious disease, or group of diseases rather, is well brought out. After this, the number who died from perforated ulcers of the stomach and intestine (2,625), from appendicitis (976), and from diphtheria (988), begin to seem small, though it must be remembered that most of those who died from diphtheria need not have done so had they been previously actively immunised. It is a little difficult to understand why nearly a thousand people were permitted to die in six months, when by the simple injection treatment beforehand they could have been saved; the treatment merely consists in injecting a small amount of the toxin of the diphtheria germ, after it has been rendered harmless, in order to stimulate the body's resistance to the poison, and is completely safe.

Not content with this, 1,972 persons committed suicide during the same period, and a further 2,744 were killed in motor accidents—over one hundred each week. These figures are influenced by the war, because there are fewer suicides in wartime—at least in civilian life, and because the black-out made driving more difficult. In all these statistics it has also to be remembered that many of the people whose deaths are recorded were old and due to die in any case: if pneumonia had not claimed some of them this week, they would have died from heart

failure next. At the same time, as a result of medical advances, people are living much longer lives. Dr. L. J. Dublin, an eminent statistician, has worked out the causes of death of a group of people born about 1876. He found that one-fifth more lived to the age of fifty than would have been expected at the time of their birth; while they were growing up, medicine had learnt to cure the diseases they suffered from as young people. At the present time, 30 per cent more have lived to be sixty-five than had any reason to expect it. So there is hope for us all yet.

THE ATOMIC BOMB

A SPATE of headlines has brought it home to all the world that applied science has ushered in a new age. The atom bombs that fell on Hiroshima and Nagasaki were man's first attempt to utilise for his own purposes the basic power of the universe, the conversion of matter to energy. Until this point in history, all the power sources on which mankind depended were derived ultimately from the sun—now man started to use the power which keeps the sun going. In its effects for future civilisation, this news overshadows all other technical advances of the century.

The first hint of such a possibility arose in scientific theory about forty years ago. By the beginning of the war it had become a reasonable probability that man would soon master the technical difficulties; and, under a code of "security" which puts Aladdin's Cloak of Invisibility to shame, the job was done. The story began to appear in public when this first *Penguin Science News* was already in proof; and the news is of too great importance, the ideas behind the technique too profound and unconventional, and the technique itself too elaborate, for treatment in a hurriedly prepared News Flash. In the next number there will be several articles on the subject, written by experts who have been concerned with the long and arduous development of the theory and the technique. The following paragraphs are to be regarded as the slightest of *hors d'œuvre*, to whet the appetite for the fuller and more satisfying account which will follow.

It was John Dalton, a Manchester schoolmaster, who, rather over a century ago, persuaded the scientific world that apparently solid and continuous substances really consist of vast aggregates of little separate lumps or atoms, each atom indestructible by any process then

known. For most of this century it has been a commonplace of physics that atoms are constructed of an outer system of minute electrical particles (the electrons) which revolve round a much heavier nucleus. The constitution of the nucleus has been one of the great puzzles of the last two decades. It is not yet completely solved, but at least we know that various sorts of electrical particles can shoot out of nuclei—whether they exist as such inside is another question. One of these particles is the neutron, which is characterised by possessing no electrical charge. It is therefore not particularly attracted or repelled by the electrical charges on other parts of the atom, and is a useful projectile to shoot at atoms—instead of being pushed away by electrical forces it stands a good chance of penetrating deep into the structure.

Most atomic nuclei are very stable. Naturally, they have to be; if an atom breaks up very easily, the chances are that it would have done so already and disappeared in the course of the earth's history. But a few of the very heavy atoms, where large numbers of particles are packed together into the tiny nucleus, are unstable to some extent, and break down from time to time, shooting out electrons, or other types of particle. These are the radioactive atoms; and it is the particles from these that scientists can use as projectiles to bombard other more stable substances.

The release of atomic energy in large quantities occurs in very few of these bombardment reactions. In most cases more energy must be put into speeding up the projected particles than is given out by an atom which gets well and truly hit. The first exception which looked like offering the possibility of a practical process was found when neutrons were used to bombard a particular type of uranium—U 235, one of science's cryptic names which one would not have guessed, ten years ago, would ever have made the headlines and flowed so glibly off people's tongues in the streets. Uranium is one of the

very heaviest atoms, and although slightly radio-active it is not particularly unstable. Like many other elements, it exists in a number of different forms, all of which have the same system of revolving electrons, but differ in the total mass, and hence in the number and kind, of particles assembled in the nucleus. It is only the variety with a nuclear mass of 235 units which gives the crucial reaction. Its special trick is that when hit by a neutron (projected at the right sort of speed) it breaks down completely into two rather large bits, which are atoms of barium and krypton, and at the same time gives out firstly an enormous quantity of energy *and more neutrons which can break up other U 235 atoms*. If one has a quantity of pure U 235, the process could therefore go on throughout the whole lump until all the atoms had been broken down. At each breakdown a large quantity of energy is liberated, and as there are an enormous number of atoms in a very small lump of matter, the total release of energy is tremendous. This energy appears as heat, and it appears in a tiny fraction of a second, at the sort of speed appropriate to the reactions of things as small as atoms. It is this huge liberation of heat in a minute lapse of time which constitutes the explosion of the atom bomb.

The first difficulty in achieving this result is to get the pure U 235. Uranium is in any event a fairly rare substance, and must be purified and extracted from the ore in which it occurs. But normal methods of purification are not good enough. They depend on utilising the chemical properties of uranium to separate it from other substances. But these chemical properties are fixed by the outer electrons of the uranium atom; they are exactly the same for U 235 as for the other varieties of uranium, such as the heavier variety U 238, which is 140 times as common. It is impossible, chemically, to separate the varieties, and an admixture of U 238 spoils the whole proceeding, because its nucleus absorbs neutrons without giving out either much energy or another particle capable of propagating the breakdown

reaction. In mixed uranium, therefore, a breakdown process does not spread through a large enough lump to yield a useful quantity of energy.

It is in the methods which have been developed for separating the varieties of uranium that the first major technical triumph of the new advance is to be found. Some experience in separating varieties of other types of atom had already been gained before the war. For instance, the "heavy hydrogen" and "heavy nitrogen" used for the biological experiments referred to on page 184 had been sorted out from the normal mixtures by methods similar to some of those used with uranium. There will be more about these methods in the next number.

But in the uranium story one method of separation has been used which seems to hint at such wide possibilities that it should be mentioned here. We have said that when a neutron given out by a disintegrating U 235 nucleus hits a U 238, it is absorbed without giving out very much energy, and without producing another neutron capable of carrying on the reaction. But that is not the whole story. The U 238 is not left unaltered; it is changed into a new element, neptunium, which is radio-active and changes spontaneously into a third substance, plutonium. There are two important things about plutonium. Firstly, if it is pure it behaves like U 235 and can support a self-propagating chain of breakdowns, each atom hit by a neutron giving out a new neutron to carry on the reaction. It is therefore just about as good as U 235 for producing a bomb. Secondly, being a different element from uranium—that is, differing not only in the mass of the nucleus, but also in the number and arrangement of its outer screen of electrons—it can be separated from uranium and purified by chemical methods, which are much simpler than the elaborate techniques necessary to sort out U 235 from U 238. The second method of making an atomic bomb is therefore to prepare plutonium from uranium and separate the two chemically.

The point where this story begins to get exciting is this. In order to manufacture plutonium, scientists have constructed the first atomic disintegration machine; and this machine gives out heat at a reasonably slow rate over a long period of time. We have here a definite suggestion that we may, in the not too distant future, be able to use atomic energy not only to produce a shattering explosive outburst of energy, but also to give us a slower, more manageable source of energy which might be used to drive normal industrial machines. If this can be done, man will have made himself independent of all other forms of fuel. This subject, again, is to be continued in our next number.

The principles of this "plutonium machine" are fairly simple. If a neutron hits a U 235 atom in a mixed lot of uranium, the U 235 splits and gives out, as we have seen, a lot of energy and more neutrons. In mixed uranium the U 235 is only about 0.7 per cent of the whole, and the chances are that the fresh neutron will hit, not a U 235, but a U 238; this will turn into neptunium, and that again into plutonium. The only thing the "machine" has to do is to control the process. The first step to arrange is that the neutrons given out should, as far as possible, hit some other uranium atom and not wander off into space. The method used is to spread the uranium throughout a large lump of material (such as graphite) which does not absorb neutrons readily. Any neutron arising inside the lump will bounce around from one graphite atom to another until either it hits an uranium atom, or reaches the surface of the lump and escapes into the air. The larger the lump the smaller the chance of the neutron reaching the surface. If there are small packets of uranium scattered through it in the right proportions, we can arrange that the number of neutrons hitting U 235 atoms by chance is just enough to give a release of energy at a reasonable rate, and the number of new neutrons produced is just enough to balance these lost through the surface. As the process

goes on, of course, more and more of the U 238 turns into plutonium, and since this behaves like U 235, the release of energy speeds up. The "atomic pile," as it is called, gets richer. This is controlled by gradually introducing plates of other material which absorb neutrons (e.g. cadmium), so that the rate of the reaction can be slowed down. One can therefore hold the atomic pile at a prearranged temperature. It may be that some device of this kind can be used as a furnace to heat steam or drive some other type of engine.

HOW TO GO ON

If you have been interested by any of the articles on the preceding pages you may like to know where you can read more along the same lines, so here is a short partial book list. Most of the books mentioned are likely to be in your local public library, but if not they will get them for you on request from the National Central Library for Students. In addition to books there are a number of magazines devoted to the advance of the sciences. In Britain the weekly *Nature* is read by most scientists, and also its American counterpart *Science*; a monthly which requires much less background knowledge and is intended for the non-scientist and not merely the non-specialist, is *Discovery*; while quarterly there are *Endeavour* and (in peace-time) *Science Progress*, the former published by Imperial Chemical Industries. The British Council produces *Monthly Science News* and the *British Medical Bulletin*, a monthly review of some aspect of British medicine, but as these are primarily intended for overseas, supply is very restricted in this country at the time of writing. Finally, from America come a popular monthly, *Scientific American*, and a weekly, *Science News Letter*, issued at 15 cents a copy by Science Service of Washington, D.C.

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Books marked * are mostly standard works and therefore on the whole more difficult; but they are included because they are worth dipping into, and parts are quite intelligible. Most of them enlarge on some topic discussed in this book, but if you require a more general reading list in any aspect of science, you can obtain full ones for a few pence from the National Book League, 3, Henrietta Street, Covent Garden, London, W.C.2.

GLOSSARY

ALLERGY is the name given to any state of unusual sensitivity existing in the human body, as for instance, a tendency to come out in spots after eating crayfish.

ANÆMIA is a lack of the red colouring (hæmoglobin) in the blood, a sign of loss of blood, or of a diet lacking in iron or other essentials, or of some disease.

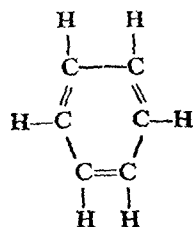
ANTIBODY. When a foreign substance, or a germ, is introduced into the circulation, the body manufactures a special protein (*q.v.*), or antibody, which has the property of linking itself to the foreigner, and thereby often of preventing the foreigner from having harmful effects.

ATOM. Some chemical substances, as mercury, iron, sulphur, carbon, oxygen, cannot be broken up by chemical means into any simpler components and are therefore called elements; the smallest part of an element which can exist separately is an atom, and its small size is indicated by the fact that about 30 million carbon atoms, for instance, cover only one centimetre when laid side by side.

A substance, on the other hand, which can be further split up by chemistry is called a compound, as for instance common salt (which can be broken up into sodium and chlorine) and water (into oxygen and hydrogen). The smallest particle of a compound is a MOLECULE, which is composed of two or more atoms of the same or different kinds, linked together in some way. (*See also* benzene, ion, isotope.)

BENZENE is an oily liquid obtained by distilling coal tar. Each molecule is made up of a combination together of a total of six carbon and six hydrogen atoms. The

carbons are arranged in a ring, each carbon also holding on to one hydrogen, thus:

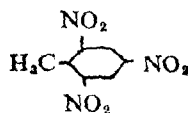


Where each letter stands for an atom.

Usually chemists write this for short as a hexagon—



which represents the actual arrangement of the atoms in space. Benzene is the parent of many drugs, dyes, and explosives. T.N.T., for example, is drawn by chemists as—



to show that attached to one carbon of the benzene ring, in place of a hydrogen atom, is another carbon with three more hydrogens (H_3) tacked on to it, while attached to three other carbons of the ring are nitrogen atoms (N), each also linked to two oxygens (O_2).

BLOOD AGAR. Agar is a dried Japanese seaweed which makes a jelly when mixed with warm water and allowed to set. It is then very useful for growing bacteria on, especially if various foodstuffs, such as meat soup, or blood, are added to the jelly before it sets. The germs of scarlet fever distinguish themselves from many other disease germs by making little bloodless, transparent patches in the blood when they grow on a blood agar jelly, which helps in identifying them for medical purposes. (See also hemolytic streptococcus.)

CALORIE is a measure of heat, just as an inch is a measure of length. It is defined as the amount of heat required

to warm up 1 kilo. (or 2.2 lb.) of water from $4^\circ C.$ to $5^\circ C.$ The amount of heat to warm the body which foods can produce can be measured by burning them in a special apparatus to find their caloric value per oz. A man needs about 3,000 caloric worths of food a day as his basic ration.

CARBOHYDRATE is the general chemical name for sugars and starches, and related compounds. They are important in foods as energy-givers, because they produce a large number of calories on burning.

CELL. When a piece of the body of an animal or plant is examined under a microscope it is seen to be made up of little blobs of protoplasm, or cells, adhering together. A number of similar cells sticking together is called a tissue. When cells of different types are together and perform one bodily function, the group of tissues is called an organ. The stomach, for instance, is an organ composed of gland cells, muscle cells, nerve cells, etc., and the muscle cells are very clearly arranged together as a sheet or tissue wrapped around the digestive cavity. (See also Nucleus.)

CENTRIFUGAL FORCE. Anything moving along a circular path (e.g. a bicycle turning a corner) tends to pull away from the centre (which is why one leans over towards the centre to keep one's balance when turning). This pull-away, or force, is "centre-fleeing," i.e. centrifugal.

CHAIN REACTION: When two substances react together chemically, what actually occurs in all probability is a series of collisions between the two kinds of molecules which result in bits being chipped off each, and bits being exchanged. Often the reaction stops there, but sometimes the fragments broken off go whizzing about, exploding of their own accord into smaller pieces, or colliding with one another and forming new arrangements of atoms. This second type of chemical reaction, where once things are started a whole sequence or chain of further reactions continues to go on of its own accord at great speed, is termed a chain reaction.

ELECTROLYSIS. A splitting up of substances by the passage through them of a direct electric current, e.g. through heated common salt, with the production of metallic sodium at one terminal and chlorine gas at the other.

ENZYME. A general term for certain protein (*q.v.*) chemicals produced by living cells and capable of bringing about various chemical reactions, though present only in traces. They are the parts of digestive juices which break up and dissolve the fat, starch, and meat of food; they are also responsible for fermentation: the word "enzyme" in fact means merely "in yeast."

EPHEDRINE is a drug obtained from a plant growing in Spain, India, China, and parts of America, and having an action on the body similar to that of benzedrine and adrenalin, which is to say that it makes the heart beat faster, raises the blood pressure, improves the working of the brain, etc.

EPIDEMIOLOGY. The study of the ways in which infections spread through groups of people or animals.

FLUORESCENCE. A property shown by some chemicals of glowing with a particular colour of light when placed in a beam of invisible ultra-violet light; or in the path of a beam of invisible electrons. For example, egg-shell glows with a purplish colour in a dark room "lit" by ultra-violet.

GLANDS. Special groups of living cells which make particular chemical substances. They either empty into a duct or channel which opens eventually to the food canal or the skin, or pour their chemical products into the blood as it washes by. Examples of the first type are the salivary glands which make the saliva and empty it into the mouth; of the second type the thyroid, making thyroxine and adding it directly to the blood.

HÆMOLYTIC STREPTOCOCCUS (*see also* Blood Agar). A kind of germ capable of breaking up blood and often

appearing under the microscope as a chain of about five spherical individuals or cocci. Representatives of this kind of germ cause scarlet fever, acute tonsillitis, middle ear infections, etc.

HORMONE. A chemical substance produced by a gland and passed into the blood (or other circulating fluid in the case of plants) with an action obvious on some other part of the body, e.g., the adrenal gland on top of the kidney makes the hormone adrenalin which it releases suddenly into the blood when the body is frightened; it is this stuff circulating which makes the skin go pale, the heart beat faster, the sinking feeling begin in the stomach.

IMMUNISATION. The injection of the poisons of disease germs, or of the poisons rendered non-poisonous, or of dead germs, into the circulation in graded doses to stimulate the production by the body of antibodies (*q.v.*) to them, so that later, when infected in the course of ordinary life, the body will be prepared to resist the invasion and attack of the germs, and the disease will not catch on, e.g., injection with diphtheria toxoid (a preparation of diphtheria poison rendered non-poisonous) builds up resistance to diphtheria and makes an attack very unlikely.

Alternatively, in so-called passive immunisation, which is good only for a few weeks and not permanent, ready-prepared antibodies are injected into the circulation to protect the individual, e.g., somebody in contact with a patient with measles can be given injections of measles antibodies to prevent them getting measles.

Inoculation, on the other hand, is the introduction of *living* germs into the body to produce a very mild, controlled attack of the disease and stimulate resistance to it so that a serious attack later is prevented.

ION. An atom or molecule carrying a charge of positive or negative electricity, and therefore moved in one direction by an electric current, as in Electrolysis (*q.v.*). Ions of the same charge repel, of different charges (one positive, the other negative) attract one another.

ISOTOPE. The description of the atom commonly used in chemistry is that of a miniature solar system—a heavy central mass, the nucleus, carrying a positive electric charge, around which spin a number of electrons, or negative charges which electrically balance the nuclear positives. The chemical behaviour of an atom depends on the size of the positive charge on its nucleus, in other words how many electrons it can hold around it, since the outer electrons are the parts of the atom which take part in chemical reactions and often bind atoms together into a molecule. Thus, any atom which has only one electron must be chemically an atom of the gas, Hydrogen. But the weight of any given atom, and hence a number of its physical characteristics, depends on the weight of the nucleus, which is not always the same in atoms chemically alike. Thus, some atoms which behave chemically like hydrogen are found to be twice as heavy, and can therefore be picked out by special apparatus. Heavy hydrogen (or Deuterium, as it is called) is an example of an isotope, an atom of the same chemical, but different physical properties.

LATEX. Milky sap from various plants.

MOLECULE. (*See Atom.*)

MONOCHROMATIC LIGHT. Light of a single pure primary colour, which is not broken up into further colours when passed through a prism—in contrast to ordinary (white) daylight, for instance, which is.

MUCOUS MEMBRANE. The kind of tissue which lines the nose, mouth and food canal, etc., and in health is always moist or "mucous."

MUSCLE is a tissue composed of muscle cells, which are of two main types, called striped and smooth, from their actual appearance under the microscope. In general, striped muscle is the muscle one controls, the muscle which moves the fingers, and which is eaten as meat; while smooth muscle is the kind found in the stomach, the blood vessels, the womb, which contract and relax independently of one's intentions.

NUCLEUS. (a) The heavy, central part of an atom (*q.v.* and *see also Isotope*).

(b) A darkly staining spherical body found in all cells (*q.v.*), apparently essential to life and containing the chromosomes which transmit all inherited characteristics from the parent into every corner of the offspring.

OXYGEN. A gaseous element present to the extent of about 20 per cent. in ordinary air at sea-level, and essential to the existence of human, but not of all, life; and for burning things. Produced in large amounts by green plants in sunshine.

PLACENTA. A special kind of sucker which attaches the unborn child to its mother's womb, through which it gets all its food supply. It is born after the child, as a disc about ten inches across and weighing about a pound.

POLYMERISATION. Under certain circumstances, molecules or atoms of the same substance can be persuaded to link together to form bigger and bigger molecules. This process, polymerisation, is the basis of the manufacture of plastics, which are made up of molecules of colossal size.

PRECIPITIN TEST. When a germ is injected into the blood stream of an animal, antibodies to it are made by the animal. These antibodies are almost entirely specific for the kind of germ which calls them up. If a little of the appropriate antibody from the blood is added to a suspension of the individual organisms of the germ, they become stuck together by the antibody and fall in visible clumps to the bottom of the tube. Thus, with a set of different kinds of antibodies available it is possible to have a very delicate test for the presence of different kinds of germs. The same test can be done not only with whole germs themselves, but also with an extract of them: this is the Precipitin test.

PROTEIN. A group of chemical substances with large molecules made up of several thousands of atoms, and

VITAMIN. Any organic chemical substance other than a fat, protein, or carbohydrate, which must be present in a definite but minute quantity in food to maintain full health.

CONTRIBUTORS

SIR LAWRENCE BRAGG, F.R.S., is Cavendish Professor of Experimental Physics in the University of Cambridge (the previous occupants of the Chair being James Clerk Maxwell, Lord Rayleigh, Sir J. J. Thomson, and Lord Rutherford) and the son of the late Sir William Bragg, with whom he collaborated in classical researches on the way in which atoms are arranged in various sorts of crystals, as shown by X-rays. For this work he received a Nobel Prize in 1915, and he is also an honorary Doctor of Science of the Universities of Dublin, Leeds and Cologne. He is married, with two sons and two daughters.

ERIC M. CROOK was born in Australia thirty years ago, and graduated in physics and chemistry at Melbourne University. He then came to England on a scholarship to study biochemistry at Cambridge under Sir Frederick Gowland Hopkins, and worked on the enzymes of green plants, and later on the chemical nature of the poisons produced by the germs of gas gangrene. He is now at Rothamsted Experimental Station, using the electron microscope to study the proteins of green leaves, and plant viruses, which are responsible for many fatal diseases in the potato, tomato and tobacco plants.

D. D. ELEY is a physical chemist who has spent most of his scientific life at Cambridge studying the theory of catalytic reactions—why atoms and molecules combine together and react, and what encourages them to do so faster. So far his work has been mainly on reactions interesting to industrial chemistry, but he is hoping now to investigate the way in which living things use catalytic reactions in their chemistry.

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* Now published in Penguin.

