by no means be termed chemical industries. Attention must, therefore, be directed to the by-products of butter and cheese manufacture, *viz.*, skim-milk and whey and their utilisation in special ways. Not more than 5 per cent. of the total skim-milk produced in New Zealand is dried, the rest being used as pig feed. Efficiency of conversion of milk solids into pig flesh is low and high-grade proteins are wasted in the process. The technical problems of utilising skim-milk are connected with dehydration and storage which will allow of entirely satisfactory reconstruction, marketing in areas of low purchasing power with the best methods of addition to the protein-poor diets of such areas. Uneconomic utilisation of whey also leads to a large overall loss of high-grade proteins. The New Zealand process of manufacturing lactose from whey is technically efficient. Due to the expansion in the world market for lactose during the past three years, largely in connection with the manufacture of penicillin, the present prospects for the industry appear bright. The concentrated mother liquor left over after recovering lactose are now used entirely as stock feed. Nothing promising has emerged from the work done towards a more economic utilisation of this product. Production of casein from skim-milk is strictly controlled due to the demand for pig meat by the United Kingdom and the consequent necessity for retaining skim-milk for pig feeding. Casein is likely to hold its own as an adhesive in plywood manufacture and while there is a field for some expansion in casein plastics there is a constant threat from synthetic resins and plastics. Among the by-products of the meat industry prospects for rennet production in the post-war period are encouraging and the current economic policy furnishes the leather and hides industry an assured internal market. A sound gelatin industry which is now operating, can offer adequate supplies of raw glands, particularly the pancreas and the pituitary, for the preparation of hormones in New Zealand itself. A more economic use of blood than its conversion into fertiliser is a major piece of investigation in which New Zealand is particularly interested. Fish liver oils and sea-weed products such as agar and alginic acids appear to have real potentialities. Tree growth in New Zealand is rapid and her exotic forests can be greatly extended. More efficient utilisation of the products of the timber and pulping industries is an urgent problem facing New Zealand in common with all timber producing countries of the world and justifies considerable expenditure on research work. In view of the natural advantages possessed by the New Zealand flax plant, *Phormium tenax*, in high fibre yield per acre, intense investigation on the plant and its fibres which have been hitherto sporadic, is fully warranted. The phormium fibre cannot be utilised for rayon manufacture but a high-grade paper can be made from it. The small tobacco industry of the country provides enough waste material and there seems no reason why about half of the country's needs of nicotine should not be obtained from locally grown tobacco. The war-time enterprises of successfully growing on small areas *Digitalis purpurea, Dattura stramonium, Belladorna and Hyoscyamus* for home consumption and foreign export, deserve to be consolidated during the post-war era, since inquiries for further supplies of the drugs have been received from both English and Australian firms.

ON PHYSICAL ANALOGY—ITS USEFULNESS AND ITS DANGERS

By D. FERROLI, S.J., D.SC.

Introduction

CURIOSITY is the beginning of Science. Curiosity leads to *observation*, which studies facts, follows their development, inquires into their origin. After observation comes *classification*, whereby facts are arranged into various categories, according to their similarity or otherwise. A third step may be described as *formulation*, when the *law*, which is suspected to underlie the uniformity with which facts present themselves, is given a succinct verbal shape, to be—whenever possible—expressed by a mathematical formula. But the formula is—by its very nature—universal, and must be verified; *i.e.*, formulation demands *verification*, which is obviously done by further observation and experiment.

2. The Main Scope of Analogy in Physics is Explained by Means of an Example

To guide the physicist to develop his ideas, without committing himself to a definite theory, *Analogy* plays a most important part. By *Physical Analogy* we understand—with Clerk Maxwell—"that partial similarity between the laws of one science and those of another, which makes each one of them illustrate the other".

When the study of *Solutions* was first undertaken, and the main facts observed and classified, it became soon apparent that the solute existed in the solvent in most minute particles, which seemed to be in continual agitation. The question was soon asked: May not these particles behave in the solvent, as the particles of a gas behave in a closed vessel?

If that was so, the *Kinetic Theory of Gases*, so magnificently built up by the genius of Clausius, Maxwell and Boltzmann could perhaps be used to illustrate the behaviour of solutions. The suspected *Analogy* might also, eventually, lead to the discovery and formulation of a law. Now the first formula of the Kinetic Theory embodies the Laws of Boyle-Mariotte and of Charles. Could a similar formula be applied to solutions?

As is well known, Pfeffer found that, in the case of dilute cane sugar solutions the osmotic pressure, at a given temperature, is nearly proportional to concentration. Also, the osmotic pressure, for a given concentration, is proportional to the absolute temperature.

This, of course, means that the Laws of Gases hold also for dilute solutions, and Van't Hoff left justified in asserting that the osmotic pressure of a solution is equal to the gas pressure which the solute would exert if all the solvents were removed, and the dissolved substances were left in the space in the condition of an ideal gas.

In this case similar, or analogous behaviour was first suspected. Experiment proved the suspicion to be correct. But it was Analogy which dictated the experiments, and showed the path which the scientist had to choose among an infinity of alternatives, if he was to put some order in his notions of solutions, and formulate some Law which might be a convenient indication of their behaviour.

3. A Remark

But in this way, did not Analogy limit the scientist's vision, and lead to forced conclusions?

Obviously it did limit his vision; but, paradoxically, it is only by limiting our field of view that we achieve success. A scientist, who attempts to embrace all, will grasp nothing. There is no concentration without limitation, and by concentration we gain in depth, if we loose in extension. Further, orientation imposes limitations; but research lacking orientation will prove futile.

4. A Danger

But might not Van't Hoff's bold formulation prove deceptive? Might not similarity of terms cover very dissimilar things? The possibility cannot be denied, and it appeared very real as soon as scientists tried to identify osmotic pressure with the molecular bombardment by the particles of the solute. Besides, an Analogy was asserted between the solvent and an empty vessel. But how can a solvent be assimilated to a vacuum? Are the interstices between the particles of the solvent so great in comparison with the molecules of the solute, as to allow a certain plausibility to the view that the behaviour of particles in dilute solutions is analogous to the behaviour of gaseous particles *in vacuo*?

Yet Boltzmann showed that, on the assumption that the *Law of Equipartition of Energy* holds for the solute, the laws of osmotic pressure necessarily followed. But scientists were somewhat suspicious of Boltzmann's mathematical methods as applied to solutions, for, in the words of Clerk-Maxwell, "the excessive use of Mathematics in Physics may make us lose sight of the phenomena to be explained; and though we may trace out the consequences of given laws, we can never obtain more extensive views of the connexions of the subject".

It is good to remember that mathematics—as applied to physics—systematizes, summarizes, simplifies, but does not, by itself, lead onwards. Progress is mainly due to Experiment and to Analogy.

5. Another Example

And Analogy led on Jean Perrin to study *Emulsions*, and see if the *Law of Equipartition of Energy*, which is the corner-stone of the Kinetic Theory, might hold for them also. Pfeffer had shown that a molecule of sugar, with some 40 atoms, acts like a molecule of hydrogen with only 2 atoms. Perrin went further, and surmised that there was no limit to the grouping of atoms, and that the law holds also when groups are so complex as to be visible to the microscope. Then, of course, a corpuscle, which takes part in the so-called *Brownian Movement*, and which consists of millions of atoms, ought to behave like a hydrogen molecule. If it is so, *Emulsions* obey the Laws of Gases, and it must be possible to determine *Avogadro's Constant* from their behaviour. Perrin's wonderful experiments led him to the determination of that very important number, his results lying between $60 \cdot 10^{22}$ and $70 \cdot 10^{22}$. A remarkable achievement indeed.

6. Caution

We shall digress a little, though, as it will be seen, the digression has a certain bearing on the matter in hand.

All will admit that there exists an Analogy between a map (say) and the country which it represents. From the map one can find distance, direction and orientation between two places. The map will tell us whether a district is hilly or not, wooded or cultivated, rich in water or rich in sand. Yet, how different is the knowledge of a country which we gather from a map, and the knowledge we acquire by visiting it. Map-knowledge—so to call it—is not to be despised, but it lacks life and fulness. Map-knowledge is not false; yet how poor and meagre, if unaccompanied by real knowledge.

The same may proportionately be said of the knowledge of one science gathered only from the Analogy with the Laws and formulæ of another science. The formulæ need not be false, but the knowledge they impart is meagre and inadequate. It must needs be filled up and implemented by experimental knowledge. The beginner is always under the danger of resting content when, either by Analogy, or by the free use of Hypothesis, or in some other way, he has given mathematical expression to a Law. To take an example from Clerk-Maxwell: "The Laws of uniform motion of heat in homogeneous media are mathematically identical with those of attractions varying inversely as the distance. Hence, if we knew nothing more than is expressed in the mathematical formulæ, there would be nothing to choose between one set of phenomena and the other". Similarly the Laws of Gases, of dilute solutions and of emulsions, are analogous. The formulæ which represent them are the same. Yet the difference is considerable.

7. A Third Example

As already remarked, *the Law of Equipartition of Energy* is the foundation of the Kinetic Theory of Gases. By a stroke of genius, Eddington extended the Law to the stars. Already in 1911 Halm had suspected a certain equality between the kinetic energies of light and heavy stars In 1922 Seares showed that the surmised equality was real. Eddington then studied the problem of the distribution of density, pressure and temperature in the interior of a star. The forces coming into play are gravitation and the pressure of radiation. Observation furnished the data of mass, density and quantity of heat radiated by the star in unit time. Owing to the exceedingly high temperatures and to the so-called *Photo-Electric Effect*, the atoms in the stars are dissociated and ionised. Now, by Analogy with perfect gases, the Thermo-dynamical Theory of Gibbs on the equilibrium of gaseous systems may be applied to the electronic dissociation in the stars. Eddington then worked out the formulæ which connect the mass of a star with its radius, its temperature and the quantity of energy which it radiates. For instance the temperature at the centre of the Sun is $4 \cdot 10^{7}$ °C. and its pressure, $133 \cdot 10^{7}$ atmospheres. He found also that if the mass of the star is less than 10^{32} gms. the radiation pressure is very small in comparison with that due to matter. On the contrary, if the mass exceeds 10^{35}, the material pressure may be neglected. From astronomical data he constructed his famous *Curve*, which afforded a sufficient test for his theory. But it proved something more.

In the beginning it was believed that Eddington's theories, founded as they are on the Laws of perfect gases, applied only to giant stars. For it seemed inconceivable that the Laws of Boyle and Gay-Lussac could be valid for stars with a density several times that of iron in their interior. But observation showed on the contrary that the properties of gases are to be applied to all the stars (*f.i.*, to *Capella*, whose density equals that of air, and to *Krueger*, sixty times as dense as iron). The thing was astounding. How an explanation was sought and found in the new ideas on the constitution and disintegration of atoms is most interesting, but it far exceeds the limits of the present article.

8. CONCLUSION

What has been said, however, is sufficient to show the fruitfulness of *Physical Analogy*. By *Analogy*, not only does the scientist systematize his knowledge; he further extends and develops it. *Analogy*, by suggesting the formulation of a Law, will direct the choice of experiments. No doubt, an injudicious use of *Analogy* may lead to a distorted view of nature. Also, merely analogical laws may result in knowledge that is formal and almost nominalistic. Experiment, however, will keep our feet firmly planted on Earth—which will eventually prove to be a spring board enabling the mind to fathom the innermost secrets of the stars.

TONUS IN STRIATED MUSCLE

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THE mechanism by which a state of partial contraction of striated muscle, or tonus, is produced remains enigmatic. The explanation most generally accepted is that a rotational excitement of motor units occurs, one group being released as the next contracts.[1] The excitations would have to be properly timed in order to produce an even and imperceptible contraction as that of tonus. If this were true it would be expected that action potentials led from small aggregates would reveal rotational bursts of impulses. Such a phenomenon has not been capable of demonstration.[2]

Light on the tonic contraction of striated muscle is thrown by studies of similar contraction in unstriated muscle. The chief characteristics of tonic contraction of skeletal muscle are: (1) The metabolism (oxygen consumption and carbon dioxide output) is low when compared with that of muscle when executing movements; it is only about 25 per cent. higher than that of completely paralysed muscle. Posturing muscle is also relatively infatiguable; the deverbrate cat may stand for six days without signs of exhaustion. A small (needle) electrode placed into a muscle unit, shows that it contracts synchronously but responds at a low frequency, *i.e.*, 5-20 per second indicating a correspondingly low rate of discharge from the anterior horn cells.[3] The tension exerted is far smaller than that given by the same muscle when it is stimulated at a high rate (*e.g.*, 100 times per second) through its motor nerve.

Skeletal muscle contains red fibres, rich in sarcoplasm, poorly marked transverse striations and nuclei scattered throughout the substance of the fibres. They contract slowly after a long latency, the duration of contraction being three times that of the more quickly acting and more highly differentiated pale fibres. Red muscles go into tetanus at a low rate of 5 to 8 stimuli per second.[4]

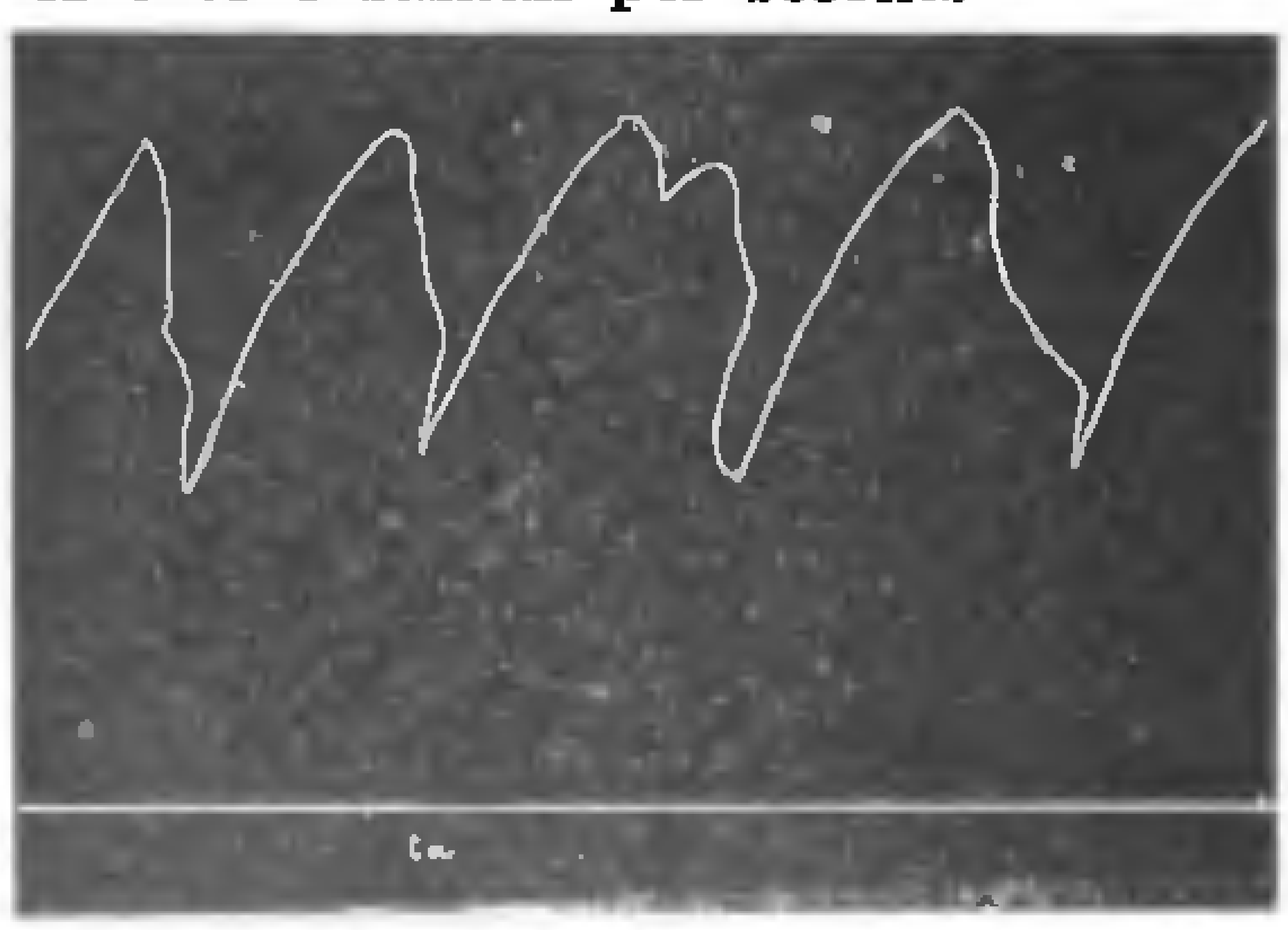

FIG. 1. Mytilus muscle in saline with 0·02 M $CaCl_2$; Barium 0·07 M $BaCl_2$

Now, let us compare the above facts in striated muscle with those in unstriated muscle. Unstriated muscle can be tetanised if stimulated at a much lower frequency than striated muscle; various unstriated muscles in the body may differ in this respect, just as red and pale skeletal fibres. The metabolism of tonic contraction is lower than that of twitch contraction.[5] If *Mytilus muscle* is