in a large measure, be restored by abolishing contracts of the post-costing type entirely. Costing in the engineering industry, if tackled on common-sense lines, is relatively simple if only the men who know are consulted. Years of bargaining over piece rates have made every shop steward an expert. Any junior clerk can cost materials. Accumulated experience, if it were only collated and used, should by now have made loading for overheads almost rule of thumb for any given type of work. It *is* possible to fix contract prices in advance over the major part of the field and fix them at keen prices. If any contractor says he can't turn out the goods at the standard or scientifically pre-determined price, there is always Regulation 78, which empowers the Government, after having put in a controller, to take over, lock, stock and barrel, any firm which is considered obstructionist. And there are many workers at the benches and lathes who would make as good, if not far better, managers, individually or collectively, than a large proportion of those now holding managerial positions. Sufficient testimony is the magnificent equipment of the Red Army and Air Force.

Dialectical Materialism and Modern Science

III.—Quantity and Quality

by J. B. S. HALDANE, F.R.S.

THE transformation of quantity into quality, and conversely, was regarded by Marx and Engels as a fundamental dialectical process. Marx states one aspect of it very clearly, when writing of the relation between small savings and capital. "Here," we read, "as in natural science, is verified the correctness of the law discovered by Hegel in his 'Logic' that merely quantitative changes beyond a certain point pass into qualitative differences." Engels used the phrase to describe four slightly different facts. The "transformation" could either be a process actually undergone by a material system, as when the taut rope parts under the pull, or a change found as we pass, in thought or perception, along a series of things which can exist at the same time, such as the paraffins. He also applied it both to gradual changes such as the melting of waxes, which have no definite melting point, and very sharp ones such as the melting of ice. Doubtless a sudden transformation of an object or system shows the principle in its sharpest form.

The mechanics of Galileo and Newton were based on the ideas of continuous space, time and motion, and the contradictions inherent in the latter, pointed out by Zeno and others, were ignored. The classical mechanics could explain some sudden changes. For example, it was clear why a stick suddenly fell when it was gradually pushed off a table, and it was hoped that all sudden changes would be explicable in this sort of way. However classical mechanics have been unable to explain such simple phenomena as the breaking of a bar, or the boiling of a kettle. By explanation I do not, of course, mean merely verbal explanation, but numerical explanation, which would enable us to calculate, say, the boiling point of water from simple properties of hydrogen and oxygen atoms.

During the present century it has become clear that only some of the laws of classical mechanics apply to atoms. They apply to large bodies consisting of many billion atoms simply because they are statistical consequences of the pooled motion of many atoms. This fact was predicted two thousand years ago in Epicurus' and Lucretius' doctrine of *clinamen*, according to which atoms showed a less regular behaviour than larger bodies. They do this because, under some circumstances at least, motion is only transferred to or from an atom in definite quantities, whereas according to classical mechanics it could be transferred continuously. In particular angular momentum, or spin, is only transferred in definite units, or quanta, which are the same for all atomic events. An atom can exist in a number of different states, with different spins. And

these states are qualitatively different. An atom with more than the minimum spin is liable to give out a flash of light. It is generally more active chemically than one with less spin, and so on. In fact, the transformation, and what is more, the abrupt transformation, of quantity into quality, is, at least at the level to which modern physicists have penetrated, a fundamental property of matter. Many continuous changes depend on this sharp type of change, and not the other way round.

The action of the nervous system, both in sensation and voluntary or reflex action, is based on the same principle. Every cell in the nervous or muscular system, and very probably every gland cell, too, has a threshold of excitability, that is to say a minimum stimulus which is needed before it can do anything.

Further, the activity of a cell is seldom graded. A muscle fibre contracts with all its available energy, or not at all. A nerve fibre either does nothing, or transmits a unit impulse which is no stronger, and travels no faster, if the stimulus which starts it is greatly increased. Graded activity of an organ is possible by altering the number of units, for example muscle fibres contracting at any moment, or the frequency with which each contracts. In the case of a muscle fibre a sufficiently rapid series of stimuli, each of which would cause a twitch, lead to a steady contraction.

On these principles we are beginning to understand some of the processes involved in simple sensation. A number of sensory nerves end in knobs which are sensitive to pressure. A very light pressure on such a knob may cause only a single impulse to travel along the fibre towards the brain. A moderate pressure will cause a series of impulses, at first frequent, then slowing down. A greater pressure is translated into a more rapid series, also slowing down in the end. The same seems to be true for more complicated sense organs. Our whole knowledge of the external world, and our whole action on it, depends on the numbers of nervous impulses going in and out through a few million nerve fibres. These impulses are all of the same nature, chemical changes with accompanying electrical potentials of a few millivolts. They do not seem to differ qualitatively according to whether they are destined to cause sensations of sound or warmth, pain or pleasure, or even secretion or motion. The whole qualitative richness of the external world, or of a philosopher's or poet's mind, is transformed into quantity at this level.

The change back to quality on the way inwards is only partly understood. But it depends on thresholds which vary qualitatively as well as quantitatively. Each sensory nerve fibre connects with a number of cells in the spinal cord or brain, from which more fibres arise. A large number of impulses arriving at once along fibres from the same part, as when a blow is given, will excite the relatively sluggish cells concerned in a reflex action such as withdrawing a limb. Even strong stimulation of a single end organ in the skin can probably never start a reflex, and rarely reaches consciousness. Repeated impulses along one fibre will stimulate nerve cells which do not respond to single stimuli. Simultaneous impulses from a number will stimulate cells which do not respond to repeated stimuli from one fibre, and so on. Thus as we travel up the central nervous system towards the cerebral cortex the nervous activity comes more and more to represent patterns of stimuli in the external world. And finally in the cerebral cortex the relevant patterns correspond to material objects, words, and so on, so that we are directly aware of these, and not of the series of points of pressure or colour, or isolated elements of sound, into which some philosophers have tried to analyse our perceptions.

The transformation of quantity into quality on the way out, involved in skilled muscular movement, will perhaps be easier to investigate, but has been less studied. This is probably because physiologists have so far been under the influence of philosophies which regarded sensation as more important than action—as indeed it is for a leisured class. When we know in detail how the impulses coming down the arm nerves are translated into skilled hand work we shall probably obtain many clues to the converse transformation of quantity into quality in the brain.

The transformation of quantity into quality is very clearly shown in the course of evolution. Suppose the linear dimensions of an animal to be increased 10 times, but its shape unchanged, then its bulk is increased a thousand times, but its surface only 100 times. Thus if its chemical changes go on at the same rate, each area of gut must pass in 10 times as much food per day, each area of lung or gill 10 times as much oxygen,

and so on. So the animal will only be able to live an active life if the area of the gut is increased by coiling it, throwing its surface into numerous projections, and so on. Similarly the gills and lungs must become more complex, the circulation must become more efficient, and so on. In fact, it is probably truer to say that the most advanced animals are complicated because they are large, than that they are large because they are complicated.

Many more examples might be given, but I will end on a personal note. It is often said that Marxism is somewhat of a pose in scientists who adopt it, and does not influence their research. During the nineteenth century it was found that many gases could be liquefied by cold, and Engels, among others, predicted that a quantitative change of temperature would lead to a sharp qualitative change of state in all of them. However scientists, whether or not they are materialists, were almost all unduly mechanistic. Qualities such as taste or smell were thought less real than quantitatively measurable characters such as density. Now a gas such as hydrogen sulphide with a strong smell, or carbon dioxide with a strong taste, is inodorous and tasteless until it reaches a certain concentration, which is the threshold for the human sense organs. The threshold is best measured as partial pressure. Hydrogen sulphide is first smelt at a pressure of about a millionth of an atmosphere, carbon dioxide first tasted at a pressure of about a fifth. It is obvious that a gas such as oxygen, which has no smell or taste when breathed pure at a pressure of one atmosphere, may yet be perceptible at higher pressures.

It was not, however, obvious to a number of scientists who had been at a pressure of six atmospheres, corresponding to 170 feet of sea water, because they recognized the transformation of quantity into quality in special cases, but not as a general principle, or believed in the "lesser reality," to use a phrase of Lenin's, of smell and taste as compared with shape and rigidity. So I was the first person to taste oxygen. At six atmospheres' pressure it tastes like rather flat ginger beer. At higher pressures it may perhaps develop a smell. This simple example shows that the law of the transformation of quantity into quality is not merely a convenient summary of a number of previously discovered facts (though both the quantum theory and the thresholds of nerve cells were discovered after Engels' death) but a living and fruitful guide to actual scientific discovery.

BOOK REVIEWS

The Red Army and the Finnish War

The Red Army Moves. By Geoffrey Cox. (Gollancz. 16/-).
The Soviet-Finnish Campaign. By Major A. S. Hooper. (Colletts' 3d.).

How often in discussing the chances of the Red Army in the present war one is confronted with such a question as: "Well, how was it they did so badly in Finland?" The general impression of Soviet military weakness, for which the reporting of that campaign was responsible, has had a considerable political effect in the past twelve months. While many people had from one source or another obtained facts to refute the usual libels, we have now for the first time just the comprehensive evidence we have wanted most. Firstly in Major Hooper's excellent conspectus of the campaign, and secondly in Geoffrey Cox's much fuller treatment, written though it is from a somewhat hostile point of view.

Cox, like the prophet Balaam, sets out to curse, but is constrained to bless. That is the value of the book. With a certain naiveté he first blurts out all the usual allegations and then finds himself contradicting them. Thus he sets out to describe the brutal and deliberate bombing of civilians in Helsinki, as if he himself really believed it, but after stating the facts, with an honesty and objectivity which is one of the best features of the book, he concludes: "It was not an example of indiscriminate bombing. There was no careless scattering of bombs regardless of targets. Nor was there any deliberate attempt to sow them in a purely civilian area." He goes on to say that the absence of further air raid casualties in Helsinki may have been due to the excellent shelters or to the fact that there were no more raids on the city itself, he is not quite sure which!