# CUÉNOT ON PREADAPTATION.

## A Criticism.

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No apology is needed to readers of the Review for introducing a subject so apparently remote from Eugenics as a particular theory of adaptation. Darwin's work is truly fundamental, and any considerable criticism of his main position must deserve the careful attention of all who believe the process of evolution to be a fact. A paper by Mon. L. Cuénot, of Nancy University, in "Scientia," for July, 1914, provides just such an account of the tendencies of one school of Biologists as will serve for the "point d'appui" of certain criticisms which we believe it is very much in the interests of Eugenics to make.

It will first be necessary to give a fairly detailed résumé of Mons. Cuénot's paper. He begins by discussing various theories of adaptation. Organisms show manifest adaptation to their environment. For example, moles, with their fore paws transformed into digging tools, long sensitive nose, cylindrical body, and very small protected eyes, are excellently well suited to a subterranean life. Theology first, and science later tried to explain the origin of adaptation. Isidore Geoffrey Saint-Hilaire put forward a limited transformism which commended itself to Roman Catholics, according to which the Primordial Types are the result of special creation, but genera and species are the result of subsequent modification according to natural law. The famous theory of Lamarck was based upon the moderating influence of external factors on the organism, summed up in the aphorism : "Need creates the organ, necessity and use strengthens and increases it considerably." For example, the needs of certain birds drew them to the water for prey, and they then contracted the habit of stretching the skin between the toes to beat the water. Incessant repetition produced a functional modification which was handed on to their descendants, and being increased by them resulted in the well-developed membranes between the toes which we now see. It was a process of cumulative inheritance of functional modification. Certain birds in attempting to fish without wetting the body, develop long necks, and long legs. Snakes acquire an elongated form, and lose their limbs. Flying squirrels (*Sciuroptera*) of Ceylon and Sumatra develop the skin of the flanks into large gliding membranes. Ruminants which fight by butting acquire a formation of horned or osseous matter on their heads which eventually produces horns and antlers. Lamarckian explanations are not likely to satisfy any modern biologist, even setting aside the more than doubtful assumption of the inheritance of the effects of use and disuse. The utility of webbed feet in aquatic birds and mammals is evident, but we find freely aquatic forms where the webbing does not exist. The moorhen (*Gallinula chloropus*) swims perfectly well though the toes are completely separated. The water rat has no trace of webbing, the musk rat only the rudiments. Birds which frequent river banks and marshes show every possible variation in development of the interdigital membranes. Besides all this, webbing appears in land birds among whose ancestors it is impossible to count aquatic species. The maximum amount of webbing in the case of dogs is found in the Newfoundland. Since two or three hundred years is the longest time we can allow for the duration of this race, is it possible that Lamarckian explanations can apply? We must search further than the creative effect of need and effort.

Darwin's explanation is wholly different. Adaptations established themselves by insensible gradations, each of which was to a certain extent useful to the animal, and gave it a chance of survival in the struggle for existence. It is to the constant accumulation, generation after generation, of small variations more marked in some individuals than in others that the gradual development and final state of equilibrium of the adaptations is due. Groups of individuals in advance supplant little by little those who have remained in the rear. This takes place in such a way that transitional states, no doubt represented by a small number of examples, completely disappear. For instance, in the family of squirrels, if we consider gradations between the common squirrel which leaps with agility and sciuroptera with membranes for gliding great distances, the slightest dilatation of the skin of the flanks and flattening of the tail constitutes an advantage to their possessors by means of which jumping, and escape from beasts of prey is made more easy, and danger of falling diminished. Those best endowed in these respects lived longer than the others, and left more descendants. Favourable variations were intensified in each generation, till the state of the flying squirrel was reached. An excellent example is the giraffe. In times of drought those having the longest necks could browse a little higher than the average, and a very small increase in height might make all the difference between survival and extinction. So moles with the smallest eyes, or even with eyelids joined together would survive better than others under the conditions of life in a narrow burrow. Darwin, seeking a reply to certain criticisms, notably those of Mivart, set himself to prove that every sort of *useful* transition could be conceived between a given organ taken from its origin and its final adaptation, even though that should be of the most precise and complicated nature. It will suffice to recall the Pedicellaria of Echinoderms, developed to all appearance from tegumentary spicules or granules; whalebone plates, derived from filtering lamellæ, analogous to those in the beak of the shoveller duck; serial evolution of the feet of the horse by which horses have become more and more swift of foot. When man wishes to perfect a useful quality or an adaptation in a domestic animal he copies nature and employs artificial selection. We may imagine that by choosing dogs which retrieved best in water he has perfected the well-known types of English sporting dog. It was thought that the problem of adaptation had been solved by Darwin's very clear and general explanations. It is incontestable that there are transitions between an adaptation strictly sufficient to a mode of life and the most perfect adaptation. For example, between ordinary squirrels and sciuropteres both arboreal; between a shrew mouse and a mole, both subterranean in different degrees; between an ordinary ruminant and a giraffe. But it appears doubtful whether the process of change has been quite that which Darwin imagined. It is difficult to understand how small dimensional differences such as those which can exist between examples of the same species can have such importance in the struggle for existence that they cause the survival or elimination of certain individuals even when all other conditions are equal. Besides, modern studies in heredity have shown that slight fluctuations about the mean type of a species are not in general hereditary, in such a sense that even effective selection could produce any cumulative change. These considerations throw doubt on the reality of Darwin's explanations. Nor is this all. A reproach as grave as those which precede can be thrown on Darwin's general theory of adaptations. It enables us to understand how an adaptation just sufficient can perfect itself to the greatest specialisation, each step being a useful gain. The animal becomes more and more adapted, the environment remaining constant; but the theory is no longer at all applicable when we are concerned with organs whose utility does not certainly appear until they have arrived at a terminal state of perfection. For example, the electrical organs of fishes developed independently in Torpedoes, Gymnotes, and Malapterures, have a defensive and offensive function, but the initial stages cannot have played any useful role. The same remarks apply to the luminous organs of insects. To sum up: the Darwinian explanation is incomplete, and it is necessary to find something else.

It is a question whether it is possible actually to formulate a complete theory of adaptations, explaining at once their origin and the process of their perfection. It is desired only to direct attention to at least a partial solution of the problem. Organisms display adaptation to environment, and we may ask whether a particular species did not possess sufficient and necessary adaptations before entry into that environment. If it did, then it possessed characters having a utility beyond its needs, but which have taken decisive importance at a given moment in permitting the creature which presents them to adopt a new manner of life. As Davenport has justly said:

> "The structure exists first, and the species seeks to find the surroundings which respond to its particular constitution. The adaptive result is not due to a selection

of structure suitable to a given environment (theory of Darwin and Wallace), but on the contrary to the choice of surroundings responding to a given structure."

Because the Newfoundland dog happened to possess webbed feet he has been able to acquire more aquatic habits than other dogs. One can call indifferent or semi-useful, characters in a species which become evident adaptations on removal to a new habitat or on the acquirement of new habits, *preadaptive* or *prophetic characters*, or more briefly, *preadaptations*. The following example will make this clear: the common stickleback (*Gasterosteous aculeatus*) normally a fresh water fish, is found in Lorraine inhabiting also pools and streams of varying salinity. This capacity for living in salt water, which depends upon the osmotic properties of the peripheral tissues, is fortuitous, without utility, acquired by chance. In the fresh water condition such a characteristic would remain unknown without experiments, but it becomes decisive for survival in the new habitat. Again, the Kea parrot (*Nestor notabilis*), from the mountains of New Zealand, originally insectivorous, or frugiverous has become a flesh eater since the introduction of sheep into the country, attacking and feeding upon the living animal. *Nestor meridianalis*, a nearly related species, still remains frugiverous.[1] It may be established as a general rule that the minimal amount of adaptation which permits life in a certain station, *i.e.*, what is strictly necessary, appears always in the line of being as preadaptation. Such characters appear under the form of latent properties of indifferent or mediocre utility. They have appeared by chance as fortuitous variations, and there is no occasion to seek for a Darwinian or Lamarckian explanation of them. Assuredly, the strictly sufficient initial adaptation may complicate itself, but this constitutes another problem which is not considered. It is sufficient to present this concept of preadaptation which it is thought may be applied with success in the animal and vegetable kingdom. It is curious to state that it is Darwin who first noted in the clearest fashion cases of pre-

[1] Paris, Alcan, 1911, L. Cuénot.
Refer to: "La genèse des espèces animales."

adaptation. (M. Cuénot then quotes two passages from the *Origin*. The first one deals with the existence of sutures in the skulls of young birds and reptiles, a provision which became later on of such profound importance during parturition in viviparous mammals, the second is concerned with a trailing palm in the Malay Archipelago, which climbs the loftiest trees by the aid of hooks round the end of the branches, hooks which occur on many trees that are not climbers.) Since Darwin's great book appeared no one seems to have thought of developing the idea shut up in germ in these two passages. "In 1901, without remembering, I declare, this penetrating view of Darwin, I formulated the Theory of Preadaptation."[1] Morgan in 1903, in "Evolution and Adaptation," and Davenport[2] in "Animal Ecology of Cold Spring Sandspit," expressed absolutely similar ideas. Morgan says,

> "The origin of each form has nothing to do with surroundings or with utility, and the form appears independently of the surroundings; once appeared, it can be perpetuated in suitable conditions."

De Vries remarks that station alone has chosen the suitable forms among a crowd and has no relation with their origin. The following phrase clearly indicating a preadaptation occurs in the "Tetraplasy," of Osborne, 1912, it is the more interesting coming from a very Lamarckian palæontologist:—

> "In the development of points on the molar teeth it appears that the structures can precede the functions which they will serve."

In effect, before the insufficiency of the classical explanation of adaptation by selection or by use, it is natural enough to think of adaptation anterior to the entry into an environment. The notion of preadaptation in addition co-ordinates itself perfectly with that of mutations and the Mendelian theories. Each of these three conceptions completes the others and can be considered as the triple basis of modern transformism.

Such is Monsieur Cuénot's contribution.

[1] L'évolution des théories transformistes. (Revue générale des Sciences, 12ème ann. 1901, p. 264.)

[2] Animal Ecology of Cold Spring Sandspit, with remarks on the theory of adaptation. (The Decennial Publications of the Univ. Chicago, 10, 1903.)

It will be seen that the part of M. Cuénot's paper to which the author evidently attaches most importance consists of sundry criticisms of Charles Darwin's theory of Natural Selection, and an exposition of the so-called "Theory of preadaptation," which is presumably supposed to remove some of the deficiencies of the orthodox Darwinian view. Upon examination, M. Cuénot's conclusions appear to us invalid, and his claims preposterous. We must, however, claim the indulgence of our reader, since we cannot concisely indicate where he has gone astray. The objections which can be raised to a logical and consecutive argument are easy to express. There must be some fault, either in the premises, or in the reasoning. It is otherwise when the argument turns out to be continuous only in appearance. In the present case, M. Cuénot's "theory of preadaptation" does not satisfy, or bear any relation to the objections he raises to Darwin's theory. In addition, the one solid fact which M. Cuénot is at pains to present, that animals and plants frequently do exhibit fortuitous variations, which would be of service in some other habitat, is a necessary element of Darwin's theory, and—although insignificant in itself—has been amply illustrated in the many instances of change of function on the part of an organ which we find in the pages of "The Origin of Species."

Since the paper is incoherent, and shows great confusion of thought, it will be necessary to deal with it piecemeal, and in particular we must consider the "theory of preadaptation," as expounded by M. Cuénot, and the objections he raises to Natural Selection.

The objections to Darwin's theory are three, and are all exceedingly familiar to readers of the *Origin,* since they are fully answered in that work. First, it is asserted that individual differences of animals of the same species are not sufficient to affect their chances of life. Next, that effective selection would not modify the race because the individual differences are not inherited; and finally that the initial stages of highly perfected organs, being useless, could not have been improved by natural selection. It is little short of amazing to find the three best established propositions in the *Origin* calmly contradicted. The individual differences of animals affect their chances of life in every conceivable way. There would be no meaning in the word "adaptation" if it was not so. An adaptation is nothing but a particular feature in an animal or plant, which improves its chances of life in a given environment. What could be of more importance to a tree-browsing animal, in times of scarcity, than the ability to reach a trifle higher than the rest of the herd? And M. Cuénot does not deny that giraffes do vary in stature. Even if obvious differences of high importance did not appear whenever a group of animals is studied individually, it would be obvious that an individual difference, however slight, must have, in the infinite diversity of circumstances in different situations, and over the lapse of years, a definite balance of advantage or disadvantage, which, if inherited, is represented by a correspondingly definite modification, be it great or small, of the species. Modern investigations have, indeed, shown that there is a class of slight fluctuations about the mean type of a species (due to the differences of individual environment) which are not inherited. But to say that effective selection can cause no cumulative change is to contradict the perpetual experience of breeders of all kinds of domestic animals. Is it seriously supposed that the innumerable varieties of domestic animals and plants, exactly fitted to our needs and tastes, have not been modified by the cumulative effect of selection? It is difficult to imagine why M. Cuénot allowed himself to support these two thoroughly exploded fallacies, and that without—like the early opponents of Darwin—adducing any evidence on their behalf. They do not in any way lead up to the "Theory of preadaptation," but merely give an impression of intellectual levity, distinctly prejudicial to his claims as a discoverer.

The third difficulty, that of the initial stages of highly developed organs, deserved and received from Darwin ample attention. We quote from the *Origin*:—

> "The illustration of the swim bladder in fishes is a good one, because it shows us clearly the highly important fact that an organ originally constructed for one purpose, namely, flotation, may be converted into one for a widely different purpose, namely, respiration. The swim bladder has, also, been worked in as an accessory to the auditory organs of certain fishes."[1]

[1] Origin of Species, p. 230.

In modern bony fishes (*Teleosts*) the swim bladder is a characteristic organ, its function being to counteract the effect of varying pressures at different depths. The lining secretes a mixture of oxygen and nitrogen. In primitive teleosts this organ probably exercised some respiratory function; but in lung fishes (*Dipnoi*) it has been completely transformed into lungs, though these fishes still retain gills in addition. There are three species of dipnoi: Lepidosiren, of tropical South America, in which respiration is assisted by lungs at ordinary times, breaths being frequently taken at the surface. In the dry season however respiration is entirely performed by them. Protopterus, the African Dipneust, is similar in its habits; Ceratodus, the Australian Dipneust, though it frequently breathes at the surface is never actually deprived of water. Here are examples of organs useful at all stages, and functional at all stages. Again,

> "Landois has shown that the wings of insects are developed from the tracheæ; it is therefore highly probable that in this great class, organs which once served for respiration have been actually converted into organs for flight."[1]

In barnacles (*Cirripedes*), the study of which Darwin made peculiarly his own, we find some excellent examples.[2] Very briefly, pedunculated (stalked) cirrepedes have two minute folds of skin which retain the eggs by a sticky secretion in the sack until hatched. Unprovided with branchiæ, the whole surface of the body serves for respiration. Sessile cirripedes have no folds, the eggs being loose in the sack, but in the same relative position as the folds they have branchiæ, so that the two minute folds which originally held the eggs, and together with the rest of the body slightly aided in respiration, have been gradually converted by natural selection into branchiæ.

After the large number of detailed examples which Darwin gave, it is, we suppose, universally admitted that useful gradations of structure can exist between the most undifferentiated beginning and the final highly developed organ. As a further

[1] Origin of Species, p. 231.
[2] Origin of Species, p. 232.

example we may quote the case of the electrical organs of fishes, which M. Cuénot mentions.

> "In the gymnotus and torpedo they, no doubt, serve as powerful means of defence, and perhaps for securing prey; yet in the ray, as observed by Matteucci, an analogous organ in the tail manifests but little electricity, even when the animal is greatly irritated; so little, that it can hardly be of any use for the above purposes. Moreover, in the ray, besides the organ just referred to, there is, as Dr. R. M'Donnell has shown, another organ near the head, not known to be electrical, but which appears to be the real homologue of the electric battery in the torpedo. It is generally admitted that there exists between these organs and ordinary muscle a close analogy in rudimentary structure, in the distribution of the nerves, and in the manner in which they are acted on by various reagents. It should, also, be especially observed that muscular contraction is accompanied by an electrical discharge; and, as Dr. Radcliffe insists, 'in the electrical apparatus of the torpedo during rest there would seem to be a charge in every respect like that which is met with in muscle and nerve during rest, and the discharge of the torpedo, instead of being peculiar, may be only another form of the discharge which attends upon the action of muscle and motor nerve.'
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> "Beyond this we cannot at present go in the way of explanation; but as we know so little about the uses of these organs, and as we know nothing about the habits and structure of the progenitors of the existing electric fishes, it would be extremely bold to maintain that no serviceable transitions are possible by which these organs might have been gradually developed."

Turning now to the "theory of preadaptation" we find it to consist of the fact that organisms in one habitat often present variations which would be of use in another, and in virtue of such variations many successfully change their habitat. To the student of Darwin it is obvious that, since variations occur arbitrarily and in all directions, variations which would be of advantage in some other habitat must occur as frequently as those which are in fact of advantage in the conditions in which the species lives; only, the species is selected by, and becomes more fitted for the struggle for existence in the habitat to which it belongs. Migration takes an important place in the Darwinian scheme, and a migration in general presupposes, not only the "minimal adaptation" of M. Cuénot, but the discovery of a more favourable place in the economy of nature than was originally occupied.

Not only does fortuitous variation necessitate the appearance of modifications which render the animal or plant better fitted for some habitat other than its own, but there exists among widely ranging and highly organised animals a strong tendency to develop organs which are versatile, that is, capable of a wide range of function. By being warm-blooded, mammals and birds are enabled to maintain their normal activity throughout a wide range of temperature, and they may therefore be said to be preadapted to all temperatures within that range. In this sense versatility is an attempt at universal preadaptation, indeed at complete independence of particular circumstances.

M. Cuénot might say that the hand of primitive man was preadapted for steering an automobile, but in truth the hand, and even more the brain of men are highly versatile organs, appropriate to a widely ranging animal, the possibilities of which are still perhaps far from being exhausted.

If M. Cuénot wishes to suggest that these preadaptations are due to a prophetic or teleological quality in the organism, which foresees a change of condition, and provides against it, then he is stepping outside the philosophy of the physical sciences, and may at least be expected to provide the strongest grounds for such a departure. If he merely wishes us to understand that these preadaptations are fortuitous and accidental instances of the universal tendency to vary, then it only remains for us to say that he has added nothing to our knowledge.

M. Cuénot gives several quotations from modern biologists, which may serve as examples of how loose phrases propagate false ideas. Mr. Morgan, for instance, remarks,

> " The origin of each form has nothing to do with surroundings, or with utility, and the form appears independently of the surroundings; once appeared it can be perpetuated in suitable conditions."

Let us be careful to distinguish between the individual form, and the form of the species. The origin of each individual form may truly be said to be independent of environment and utility; the effect of environment is to select or to reject it. But it is this very selection which has insensibly modified the species, and produced the finest and most exact relations between the form and its surroundings. The origin of the form of the species lies precisely in its surroundings, and its needs among them. The quotation from Davenport displays a further development of the same confusion.

> " The structure exists first, and the species seeks for or meets the environment which responds to its particular constitution; the adaptive result is not due to a selection of structure suitable to a given environment (theory of Darwin and Wallace), but on the contrary to the choice of an environment responding to a given structure."

For " species " read " individual," and a grain of truth emerges. The environment of a species, however, is nothing less than the total surroundings, organic and inorganic, of all its individuals; this cannot be changed save by universal migrations, or universal changes of habit. These changes do, no doubt, very slowly take place, as the climate and organic surroundings are slowly modified. But selection is going on all the while, between all the individuals, according as they succeed or fail in perpetuating themselves under the conditions determined by the environment of the species.

So melancholy a neglect of Darwin's work suggests reflection upon the use of those rare and precious possessions of man—great books. It was, we believe, the custom of the late Professor Freeman to warn his students that mastery of one great book was worth any amount of knowledge of many lesser ones. The tendency of modern scientific teaching is to neglect the great books, to lay far too much stress upon relatively unimportant modern work, and to present masses of detail of doubtful truth and questionable weight in such a way as to obscure principles. Everything depends upon the view the lecturer takes of his responsibilities. Experience in the lecture room suggests that his main concern is, in most cases, to be "up to date." Credit must, no doubt, be given for the assumption that students will themselves turn their information into knowledge by reference to co-ordinating principles; but this course is not urged upon them. How many biological students of to-day have read the *Origin?* The majority know it only from extracts, a singularly ineffective means, for a work of genius does not easily lend itself to the scissors; its unity is too marked. Nothing can really take the place of a first-hand study of the work itself. Many lecturers give the impression that they are using a great work merely as a background against which to display the brilliance of modern research. Eagerness to announce revolutionary discoveries is an unfailing sign of a superficial intelligence, and is surely beneath the dignity of the Professorial Chair.

The specialised research worker is always ready to sneer at the man who prefers the labours of mental abstraction. About brilliant detailed investigation there is certainly something sensational not commonly associated with the creative thought which leads up to a principle. The *Origin* will never satisfy a craving for sensation, it is a long and sustained argument from cover to cover, but that is just what makes it attractive at all times to men of any mental depth, and especially attractive at a time when abstractors flourish and preoccupation with detail is almost universal. Darwin, moreover, is still the first-hand source of our most valuable knowledge about principles of biology in the widest sense.

An age of extreme and unparalleled specialisation, such as that in which we live, needs above all the steadying influence of a firm grasp on principles. Detail in itself is arid and tedious; it is moreover largely unintelligible in the absence of explanatory principle. There is too much experiment and too little thought. The inductive method exalts experiment into a position of supreme importance, but it is sometimes forgotten that the end is generalisation. The search for principle demands disentanglement from detail, and domination of it; a requirement Darwin satisfied in a very high degree. To call into being intelligence of a sufficiently high order to perform this task, so urgent at the present time in every department of knowledge, is perhaps a problem for eugenics. Certain it is that powers of mental abstraction are all too rare.

The modern studies in biology to which M. Cuénot refers are not favourable to those large abstract arguments and reasonings of which the *Origin* is so illustrious an example. Extremists have set Darwinism over against Mendelism as if some kind of antithesis existed between them. This simply shows a failure to grasp the question at issue. Darwinism is concerned with evolution, Mendelism with the mechanism of heredity. Looked at from the point of view of evolution, Mendelism presents the picture of a closed system, none the less, "this interesting discovery," as Professor Poulton has called it, has been greeted in some quarters as if it ushered in a new theory of evolution. Nothing could be more unfortunate than to belittle new work just because it is new, and it is no motive of belittlement which constrains us to say that regrettable things have been done, and more regrettable things have been said in America in the name of Mendel. Direct legislative proposals have been made, and in some cases passed, based upon quite inadequate knowledge. Persons suffering from supposedly Mendelian defects have been advised to mingle with sound stocks, though the result of doing so is clearly to lay up hereditary trouble for the future. Something must be allowed for American methods of thought, and something for their modes of expression, but when all reasonable allowance has been made can it be doubted that these things are really due to narrowness of view, to a failure to step back and take a wide survey in the manner of Darwin.

The preoccupation of the lesser Mendelians with detail is painful, and their blindness to well-established, and, so far as their own facts are concerned, co-ordinating principles, astonishing. It would seem that preoccupation with detail inhibits the use of abstract reasoning. When the whole province of life is to be considered nothing less than the clearest grasp of the widest possible generality is likely to lead to either just or well-proportioned conclusions. It is essential for Eugenists to consider on which side they ought to range themselves in this confused controversy, and that they should see clearly whither the extreme Mendelians would lead them. It is in the highest degree unlikely that Mendelism will ever cover even the field of heredity, and any amount of information about the mechanism of heredity cannot do away with the need for broad co-ordinating principles of evolution. On the other hand Darwin's work does "cover" the field in the sense that it continues to satisfy the required scientific test, that it explains and co-ordinates new facts. Arguments of doubtful validity are much more likely to proceed from new work of a specialised nature than from a well-established theory. By far the strongest ground upon which Eugenists can take their stand is that provided by general principles. They are open to all kinds of attack on the side of Mendelism, on Darwin's ground they are impregnable. It is not easy to exaggerate the importance to Eugenists of the broad principles outlined in the *Origin*. Were all information, except that used by Darwin inaccessible, such information would not only allow but compel us to formulate eugenic concepts and proposals. Changes in the constitution of a mixed population depend primarily upon selection; the existing and possible agencies of selection do at present and must always provide the most fruitful field of eugenic research. These agencies acting at large amidst a multitude of random causes, each of which may have predominant influence if we fix our attention upon a particular individual, nevertheless determine the progress or decadence of the population as a whole. We may borrow an illustration from the kinetic theory of gases. The several molecules are conceived to move freely in all directions with greatly varying velocities, but the statistical result is a perfectly definite measurable pressure. Controversy may rage round the nature and properties of the atom, yet our knowledge of general principles enables us to calculate gas pressures with accuracy. We are independent of particular knowledge about separate atoms, as in eugenics we are independent of particular knowledge about individuals. It is by no means suggested that such knowledge is not of the highest importance, interest and use. It is, however, unnecessary alike for a general theory of gases and for a general theory of eugenics.