Man and the New Biology

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Foreword

It is just a hundred years since Darwin published the book which stirred up an angry debate on whether a god or an ape was the father of the human race. As the passion evaporated from that argument, it gradually became clear that biologists had something important to say on two quite different questions—the conditions of human survival on the earth, and the nature of man.

In a sense all the lecturers were addressing themselves to these two questions. The audience, and, happily, now a much wider reading public, were warned by Professor Slatyer, a biologist, about the conditions of survival. He was followed by the psychologist, Professor Seagrim, who opened his window on the subject, and then Dr Earle Hackett moved on from the question of survival to give a doctor's summary of what a human being looks like to anyone who has absorbed the new biology. The series closed with Dr Freeman's refreshing look at the effects of the new biology on the social sciences.

From what I have said it may seem that the lectures were 'heady' stuff for intellectuals. Oddly enough, for the non-specialist they had two quite delightful surprises. One was that it was possible for the layman to understand the new biology. The other was that in 1969 it was the duty of everyone who cares about the future of mankind and the planet on which he dwells to look to the biologists, not just for knowledge, but also for the getting of wisdom.

Manning Clark

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Man's Place in Nature

R. O. SLATYER

DURING the history of the world since its primeval beginnings countless species of organisms have evolved. Some have persisted for lengthy periods of time, even in geological terms, others for much briefer periods. Their persistence has depended on the degree to which they have been able to cope with and adapt to the continuous changes in their total environment, with its physical, chemical, and biological attributes.

Man too is a living organism, whose continued survival is subject to the same restraints. There is, however, an important difference between man and all other species. To an unprecedented degree, man is capable not only of influencing the distribution and abundance of other species, but of changing the environment itself.

This means that man is truly capable of ensuring the persistence of his own species on this planet forever. Surely this must be his basic motivation. At the present time, however, many of his actions do not appear to be consistent with this long-term objective. As he has manipulated the environment, and other species, his own numbers have increased dramatically and are still increasing. The demands of each individual on the environment are themselves increasing. Yet the capacity of the environment to supply these needs is limited and man's exploitation of the environment tends to reduce that capacity. Far from ensuring his survival, this constant growth of numbers and needs constitutes the greatest threat to it. It is for these reasons that it seems true to say that man's future existence on earth is threatened by no species other than himself, yet I believe the knowledge is at hand to remove that threat.

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The thesis I wish to develop in this lecture is that failure to observe some basic ecological principles has put man into this present position. Ecology is the study of organisms in relation to their environment; it deals with the environmental requirements of single species and with whole populations or communities, with the way in which organisms influence, and are influenced by, their environment, and with the way in which organisms interact with one another. If man is to persist on this planet indefinitely, I believe he must adopt a new ethic, based on ecological premises, to guide his future activity.

I would like to consider first aspects of the evolution of the global environment itself, and of the way in which organisms live together, finally looking at the effect of man's past activities, and pointers to the future.

The history of the earth as a planet still contains many secrets and considerable controversy surrounds aspects of its formation and early development. As far as man is concerned, it is the evolution of the atmosphere and the hydrosphere which is of particular interest, since both are quite essential to life as we know it. Without these thin surface films, the earth would be exposed to wide temperature extremes, the land would be bombarded by lethal radiation, and it would not contain the water and gases necessary for biological activity.

As a crude analogy, the barren surface of the moon provides a useful illustration of their role in creating a favourable environment for life on earth.

The atmosphere and hydrosphere only represent a tiny fraction —about one-fortieth of a per cent—of the earth's mass. The atmosphere itself represents only one-third of a per cent of the hydrosphere.[1] As we all learn in high school physics, its mass would be equivalent to a layer of water covering the earth to a depth of about 33 feet. Even so, the actual quantities involved are very large. The atmosphere converted to the density of water and heaped on the continent of Australia would form a layer almost half a mile deep. The oceans would form a layer about 150 miles deep.

It now seems to be generally accepted that the primitive earth

[1] B. Mason, *Principles of Geochemistry*, 2nd ed. (New York, John Wiley and Sons, 1958).

had virtually no atmosphere or hydrosphere (at least in the context of their present characteristics) and that both have accumulated gradually during geological time as a result of the escape of water vapour, carbon dioxide, nitrogen and other substances, from intrusive and extrusive rocks within the earth's interior.[2]

Before the evolution of life much of the water vapour so evolved had condensed to form the oceans. Many of the other gases dissolved in the water so formed. Carbon dioxide and nitrogen, after water probably the main constituents of the volcanic emissions, followed different paths. Carbon dioxide, as well as dissolving in water, was continuously removed by reaction with silicate rocks to form, in a series of geochemical reactions, carbonates and silica, the former becoming the first of the great sedimentary rocks of today, the latter the ubiquitous mineral of the contemporary earth's surface. Largely in consequence, only trace amounts of CO_2 remain in the atmosphere although these amounts are of great significance to man. By comparison, nitrogen, relatively insoluble in water, was also relatively inert chemically and tended to accumulate in the free atmosphere.

Compared with today's atmosphere, this pre-life atmosphere was probably almost oxygen free, and its carbon dioxide concentration may have been significantly higher. The general temperature range was probably not much different from today. Mean temperatures may have been higher than now because higher concentrations of carbon dioxide would have tended to accentuate the 'glasshouse' effect of the atmosphere (like glass, CO_2 permits shortwave solar radiation to reach the earth's surface, but impedes the escape of longwave thermal radiation). Even so, temperatures were probably still well below the boiling point of water.

Another important difference, linked closely with the relative absence of oxygen, was the absence of ozone. Ozone is a remarkably effective filter of ultra-violet (U-V) radiation; its absence meant that radiation of this wavelength reached the earth. U-V radiation has a substantially higher energy content than visible radiation, so much so that it can photochemically dissociate many molecules. This meant that the atmosphere and surface layers of the hydrosphere became a vast chemical factory in which this

[2] W. W. Rubey in *The Origin and Evolution of Atmospheres and Oceans*, ed. P. J. Brancazio and A. G. W. Cameron (New York, John Wiley and Sons, 1963).

energy enabled many types of organic compounds to be synthesised, including the chemical building blocks required for organic metabolism and self-replication.[3] In consequence, in the period between the earth's formation and the appearance of life, the oceans became what has been termed a 'dilute soup' of organic molecules.[4]

From these building blocks, and in this reducing environment, the first life processes appear to have emerged about 3·5 billion years ago,[5] and the first tremendous step towards the evolution of man occurred. It seems likely that the first self-replicating entities appeared in deep and protected waters. Since U-V radiation destroys biologically active molecules and is in fact lethal to life as we know it, life must have emerged in water at depths below the zone of penetration of U-V radiation (about 30 feet). The waters were almost certainly protected ones, since active stirring of the water by wave or tidal movements would have brought these first life-forms closer to the surface and into the zone of influence of disintegrating U-V.

It is not appropriate to detail here what is known of the exciting story of organic evolution—the development of the cell membrane, of the single cell and of multicellular organisms, of the various refinements and adaptations, that led to man. Many books have been written, and will probably be re-written, on this subject. There are, however, some highlights of the evolutionary record which I do wish to mention because of their environmental as well as their biological significance.

The chief of these concerns photosynthesis, the process by which green plants convert a flow of solar energy into stored chemical energy. This is the process on which all of us, directly or indirectly, are still dependent for our food supplies, our clothing, our fuel and power, and much of our shelter.

To those of you who have not appreciated this fact, it is rewarding to meditate a little on the origin of our food, clothing, fuel, and shelter. Apart from nuclear or hydro-electric power, and from mineral-derived building materials, virtually all our needs come either directly from plant products, or indirectly from animals and from fossil fuels such as coal, oil, and natural gas.

[3] H. C. Urey, *The Planets: their origin and development* (New Haven, Yale University Press, 1952).
[4] J. B. S. Haldane, *Science and Human Life* (New York, Harper, 1933).
[5] P. E. Cloud, jun., in *Science* (1968), **160**: 729.

The first forms of life were heterotrophic, dependent on outside food sources—of chemical nutrients—for their survival. Although when life first appeared the 'dilute soup' was so abundant that ample chemical energy in the form of nutrients was available for nutrition, it is clear that life could not persist indefinitely unless it became autotrophic—able to be self-sufficient for its basic energy needs. The evolution of photosynthesis provided the key for this autotrophism. Photosynthesis utilises carbon dioxide and water, as raw materials, producing carbohydrates and oxygen, while storing solar energy in the intra-molecular structure of the carbohydrate molecules. In the presence of adequate carbon dioxide the rate of photosynthesis is closely dependent on light intensity.

The building blocks for photosynthesis were also formed in the 'dilute soup'; the first photosynthetic organisms are thought to have appeared about 2·7 billion years ago.[6] Like their non-photosynthetic cousins, they were restricted to deep water by the need to avoid U-V damage; at these depths light intensity was also much reduced so that the rate of photosynthesis was initially very slow.

Until photosynthesis began, it seems that the only oxygen in the atmosphere was that formed by the photodissociation of water molecules by U-V radiation.[7] While significant quantities of oxygen were made available by this process, although at a slow rate, and also some ozone by the photodissociation of the oxygen molecules themselves, it seems likely that both oxygen and ozone were maintained at near zero levels by their rapid involvement in oxidation reactions. In consequence, the oxygen concentration prior to the evolution of photosynthesis probably did not exceed one-thousandth of its present atmospheric level.

The oxygen and energy produced by photosynthesis is consumed by the metabolism of the chains of organisms which feed on the photosynthetic products. This respiratory metabolism represents, in chemical terms, a net reverse of the overall photosynthetic reaction, energy being released as oxygen is consumed and carbon dioxide is produced. A net yield of oxygen is therefore only obtained, and a net store of energy conserved, when the photosynthetic products themselves, or fossil remnants from other organ-

[6] T. C. Hoering and P. H. Abelson, in *Proc. natn. Acad. Sci. U.S.A.* (1961), **47**: 623.
[7] L. V. Berkner and L. C. Marshall in *Journal of the Atmospheric Sciences* (1965), **22**: 225.

isms, accumulate at protected sites, such as in the ocean depths.

When photosynthesis first appeared the oxygen evolved was also rapidly utilised in oxidative reactions in the water itself, in the atmosphere, and in weathering processes on land. Very slowly, however, the oxygen concentration began to rise. When it reached a level sufficient to maintain a permanent concentration of ozone in the atmosphere, a major step forward in the evolution of life began, because the ozone began to filter out U-V radiation and reduce its intensity at the surface. In consequence, its depth of penetration in the oceans began to decline and organisms began to occupy shallower waters, in which visible radiation was higher and photosynthesis could be much more rapid.

Gradually this trend accelerated, oxygen and ozone increasing until ozone levels were high enough to shield the land surfaces of the earth from lethal U-V. This provided tremendous opportunities for biological diversity; the scope for colonisation on land can be appreciated when it is realised that the land surfaces were bare at this time. It is not surprising that in a relatively brief span of 30 million years, between the later Silurian period, 420 million years ago, and the early Devonian, virtually all the land surfaces were vegetated.

In terms of the evolution of the atmosphere and oceans the story is virtually complete at this stage; certainly by the end of the Palaeozoic era, some 250 million years ago, atmospheric gas concentrations appear to have reached levels comparable with those in existence today, and the same is true of the main properties of the hydrosphere.

The present levels of CO_2 and oxygen, both vitally important for man, are maintained by a dynamic balance between rates of production and consumption, buffered by large reserves.[8]

In the case of CO_2, levels appear to be controlled mainly by the chemical equilibrium between carbonate minerals and dissolved CO_2 in the oceans. The atmospheric CO_2 represents the gas partial pressure appropriate to the basic solid-liquid equilibrium value. However, this basic equilibrium, although effective over long periods of time, is insensitive to short-term changes in CO_2 concentration. As we shall see later, the combustion by man of the fossil fuels stored from photosynthesis over geological time has already

[8] H. D. Holland, personal communication.

changed the atmospheric CO_2 level and is continuing to do so.

In the case of oxygen, the level appears to be controlled by the relative rates of oxygen input, mainly from ocean photosynthesis and the associated accumulation of organic debris on the ocean bottoms; and oxygen depletion, by oxidative reactions, mainly associated with weathering processes. The accumulated difference between these quantities has led to the pool of oxygen now present in the atmosphere. Clearly, although the quantities are vast, a change in the rates of either ocean photosynthesis or weathering could affect oxygen levels. Man is capable of influencing these levels too, although at a much slower rate.

The reason I have taken you on this excursion through the geological past is to bring home the point that biological as well as geological events have played, and are playing, an important role in establishing and maintaining the present characteristics of the earth's physical environment. Without an ozone screen to protect us from U-V, without oxygen for respiratory metabolism, without CO_2 for photosynthesis, life as we know it could not exist.

Many other features of the environment are also vital for our existence. Almost without exception all are in a dynamic state of balance, in which biological and geological factors interact to provide the attributes that now prevail. Thus our present global environment is not a relic from a bygone age, nor is it a resource which can be exploited by man as though it were limitless, or as though change can be made in one aspect, without regard to the repercussions of that change to the whole.

In this overall environment biological evolution has led, through genetic innovation and natural selection, to the colonisation of almost every nook and cranny, every environmental niche, on earth; with a range of plant and animal species, each competing with, yet often dependent on, others for space and nourishment. In this way a range of biological environments has been developed; collectively they are termed the biosphere.

Man, although he frequently attempts to pretend otherwise, is a creature of his heredity and his environment. He has evolved through the mainstream of biological evolution and the biochemical building blocks which constitute his structure and regulate his function reflect the restraints and demands of the environments in which they evolved and to which they became adapted. Man cannot live in a range of climates much different from those on terrestrial earth (I do not regard planetary or deep ocean existences for man as living); he cannot exist without a range of foodstuffs that contain the chemical nutrients essential for his metabolism. He undoubtedly has other requirements associated with his inherited behavioural patterns. Yet man is capable of changing his environment to such a degree that some of these primary requirements could be destroyed.

Before we turn to examine aspects of man's impact on his environment, let us look a little further at some of the main attributes of life itself.

A primary feature of life on earth is that organisms do not exist in isolation; instead the entire biosphere is composed of a range of ecosystems, each of which contains a number of species and a number of micro-environments, with each species tending to utilise and occupy an environmental niche more effectively than its competitors, the whole assemblage of species tending to cohabit in a manner that provides a high degree of internal self-regulation. A forest, or a lake, provide examples of typical ecosystems, but the scale can vary widely. The entire biosphere constitutes the earth's ecosystem.

A primary feature of an ecosystem is that it tends towards self-regulation. Solar energy is absorbed by the green plants of an ecosystem, to provide, through photosynthesis, the basic energy input. Plants also absorb water and mineral nutrients from the soil. The plant components thus produced are then passed through a food chain, in which the initial products are eaten by herbivores, herbivores by carnivores, carnivores by other carnivores, and so on until decomposer organisms return the organic wastes and remnants of the organisms in the food chain to the soil, in a form that enables their re-absorption by the green plants.

In most natural ecosystems, therefore, there tends to be no net production—in the human context of a net harvest of materials. The solar energy absorbed and stored by the green plants is gradually consumed by metabolism through the food chain and dissipated as heat. Thus there is a flow of energy through an ecosystem, starting from solar energy, passing through successive forms of chemical energy—at each stage some energy being lost as heat—until it is all dissipated. Associated with this flow of energy is a cycling of nutrients through food chains so that the ecosystem as a whole tends to be balanced and self-contained.

Within an ecosystem the numbers of any one species change in response to opportunities afforded to it in the way of nutrients and space. An environmental catastrophe, such as fire or drought, generally affects some species more than others; the more successful species increase in number until other restraints develop to prevent their further increase. Similarly, invasion of an ecosystem by a new species better able to compete than some existing ones will be associated with an increase in the number of the better adapted species and a reduction in the number of the less well adapted ones. (The weeds in your garden often provide good examples of this.) An important phenomenon associated with such a disturbance is that when a new species enters an ecosystem it first encounters competition from existing species. If it is successful in gaining entry, its numbers increase until, in the absence of other competition, its own increasing numbers and demands for space and nutrients prevent further increase—that is it encounters competition from within its own species. A moral for man's explosive population increase can be seen here.

The stability of an ecosystem, its ability to adapt to invasion or catastrophe without major change, is largely a matter of its diversity. In turn this is largely a matter of the rate of nutrient cycling, or the rate of energy flow. An ecosystem with little diversity is vulnerable to invasion, and, especially if energy flow is slow, is often unable to adapt to the change, at least without a period of marked instability. The successful invasion of Australia by rabbits is a good example of limited species diversity in Australian ecosystems. The ability of rabbits to compete favourably with other herbivores for forage, and the absence of effective predators, meant that rabbit numbers increased dramatically until in many areas competition for food between rabbits themselves was the main factor limiting their numbers. The successful invasion of Queensland pastures by prickly pear is another example of ineffective competition and the absence of suitable animals in the food chain to consume it. Fortunately, the absence of predators for the insect *Cactoblastis*, introduced to control prickly pear, meant that this animal could control it effectively and the existing ecosystems, perhaps enlarged by these two species alone forming another loop in the food chain, returned to a degree of stability.

The most impressive examples of potentially unstable communities, ripe for invasion by other species, are agricultural crops, where a single species may be grown over thousands of square miles. The opportunities for invasion by 'weed', 'pest' and 'disease' species—all words of modern man's vocabulary—are tremendous.

Management of an ecosystem ('management' is another such word!), in the sense of increasing the numbers of one, or a group of species within it, and perhaps in removing them from the ecosystem so that there is a net yield, need not disturb internal self-regulation. The primary need is to ensure that nutrients continue to be recycled, that other important organisms are not adversely affected, and that there is sufficient diversity in species composition to prevent the community from becoming unstable.

So we see that nature obtains stability by allowing energy to flow smoothly through ecosystems, by retaining and recycling nutrients, and by encouraging species diversity. We should not think that natural ecosystems do not change; geological processes and climatic change bring slow changes in the composition and structure of ecosystems, as does the constant geographic movement of species and continued genetic evolution. Abnormal weather, fire and similar phenomena, bring rapid changes.

Furthermore, the species themselves change. Apart from the evolution of distinct new species, existing species change in character as environmental change induces natural selection. The degree to which a species can change in a given period of time depends on its intrinsic capacity to change—its inbuilt genetic diversity—and on its generation time. The most resilient and adaptable species tend to be those with short generation times. It goes without saying that these include many of our pest and disease species. The rapid development of immunity of insects to DDT, of disease organisms to penicillin, and of rabbits to myxomatosis reflect this property.

Let us now look at man's impact on the environment to see how he has adjusted ecologically to the biosphere in which he evolved. To my mind it is easiest to do this by looking at man in three stages of his cultural evolution—Man the hunter-gatherer, Man the herder-cultivator, and Man the technologist.

When man first appeared, of the order of a million or so years ago—a very brief period in geological time—the earth contained many of the species of plants and animals which exist today, most of the climates which exist today, and many of today's topographic features. Although the distribution of climates and the location of shorelines has changed, the range of ecological situations available for life has not changed to a pronounced degree. In many regions the first men enjoyed the same type of weather, breathed the same kind of air, ate the same kinds of animals as did Neanderthal man only a few tens of thousands of years ago, or today's huntsmen-campers in areas remote from industrial centres.

Just why man appeared when he did, and rapidly demonstrated his mastery over his environment and over other species, is still a subject of some speculation. It seems logical to argue that his substantially greater intelligence than his immediate forbears permitted him to survive and emerge from the last ice age much more effectively than most other species. His hands and brain combined to provide the imagination and capability to protect himself against temperature extremes, by the manufacture of rough shelters, or clothing, in a much more effective way than any other species. The same attributes enabled him to protect himself against predators and to obtain food in an efficient fashion. His ability to communicate intelligently with fellow men provided a basis for collaborative activity.

However, even if it is not surprising that man's superiority rapidly ensured his survival, man's place in nature, until his first deliberate activities in cultivation and animal herding, was virtually the same as that of any other creature. The first men preyed on, and were preyed on by, other animals. They gathered plant foods when and where they were available. They were, in all respects, part of the natural food chain of the ecosystems they lived in; the changes they were able to make to their immediate ecosystems were probably of minor significance.[9]

Gradually the hunting and gathering skills increased with the use of crude tools, and with the development of different strategies and procedures. Fire was undoubtedly an important factor in this regard and was man's only real instrument of environmental manipulation. The deliberate use of fire enabled man to increase primary productivity by keeping vegetation communities in a relatively productive sub-climax condition. It also encouraged the

[9] R. B. Lee and I. DeVore (eds.), *Man the Hunter* (Chicago, Aldine Publishing Co., 1968).

concentration of food animals on fresh vegetative regrowth, discouraged their concentration on burnt areas, and destroyed the cover offered to predatory animals.

Although fire could have been responsible for significant changes in the flora and fauna of some ecosystems, the degree to which it led to instability in ecosystems is unclear, since repeated burning, from natural causes such as lightning, is a feature of many sub-humid ecosystems, and fire tolerance develops as a result. For present purposes it seems safe to conclude that, while the use of fire by man the hunter-gatherer influenced the character of many local ecosystems, its effect on a regional basis may have been minor. Clearly there were no detectable changes to the environment as a whole.

The activities of the Australian Aboriginal, prior to European colonisation of Australia, in many respects epitomised the life of man the hunter-gatherer.[10] If Aborigines could not be seen, evidence of their previous presence at any location was meagre and short-lived. In most respects they were as well adjusted to the natural environment as the animals and plants they consumed.

These men really lived their natural ecological role. Admirable though this was in the sense of permitting nature's overall fulfilment, it clearly left man vulnerable as a species. So it was that man the farmer gradually emerged.

Those of us who admire the noble savage must conclude that life since the emergence of agriculture has been one long downhill slide —from fun to work. Whether or not one agrees with this view, the fact is that as man's hunting-gathering activities gradually became those of herding and cultivating, and he became a farmer, he began a commitment from which there was no escape.

As I mentioned previously, the numbers of any species in an ecosystem will tend to rise if it is protected from its competitors. Man the herder-cultivator sought to ensure his own survival by protecting his food supplies—the plants and animals he wished to consume—from competition and predation, and by deliberately cultivating them. In ecological terms he sought to maximise the energy flow passing through himself by maximising the energy flow passing through the species directly ahead of him in the food chain.

[10] R. Jones, *Archaeology and Physical Anthropology in Oceania: the journal* (1968), **3**: 201.

Because he was also able to protect himself against predation, his numbers increased, and immediately his dependence on the managed ecosystems increased further. There was no going back. Not only did he become dependent on agriculture, but his increasing numbers started a demand-supply spiral which meant that he had continually to attempt to increase both the area under cultivation and the yield of any one area.

Furthermore, the more specialised his agriculture became—the more, if you like, he attempted to reduce the number of species in his managed ecosystem—the more unstable they tended to become. The tendency for undesirable species to invade his farms increased, the removal of existing vegetation exposed his lands to erosion, and this factor, combined with the removal of nutrients from his ecosystems without replacement, began to reduce their productive potential.

Thus many of the early agricultural efforts tended to be highly exploitative, and a shifting agriculture arose. When productivity dropped, new farms were developed, and the old farmlands were left to revert to a natural ecosystem. The shifting agriculture still evident in parts of New Guinea is a good example of this.

With time, man learnt to replace nutrients on his fields by using crop residues and human and animal manure; he learnt to prevent erosion by maintaining ground cover and cultivating only level land. He developed farming systems which gave his domesticated species advantages over their competitors and predators. Crop rotation, sanitation practices, and other procedures all helped in this regard. In consequence his ecological management practices improved, nutrient cycling was restored, and levels of stability were achieved.

Although some specific ecosystems were badly damaged (for example, those on the fringes of the Sahara where herding of goats caused almost completely new, and much less productive, ecosystems to be established), man's activities, in most cases, were still of little consequence to the biosphere as a whole. Not only was his capacity for major change limited by his musclepower and that of his domesticated animals, but his numbers were still so small that there was always more land over the next hill or in the next valley.

Man the herder-cultivator was therefore able, if not to live an ecological role as fully as man the hunter, at least to avoid large-scale environmental change, although his low numbers were the main factor responsible. Even so he barely managed to match food production against increasing numbers, as periodic famine in peasant agricultural systems, even today, testifies; thus in ecological terms he was stretching the capacity of his ecosystems.

The first signs of a new problem in ecological management were also evident whenever man congregated into villages and towns. In these centres there developed great accumulations of organic debris—body wastes, food scraps, the detritus of the range of human activities. At this stage the word 'pollution' could well have been introduced to man's vocabulary. Pollution, in ecological terms, generally means the addition of materials to an ecosystem which accumulate because they overload the existing food chain pathways or because, in the modern idiom, they are 'non bio-degradable', that is they cannot be recycled at all, or at any rate fast enough to keep their levels low. In the former case the opportunities for species capable of capitalising on the extra nutrients are increased considerably; in human terms these species are frequently pathogens or carry pathogens, and epidemic disease is the logical result. In both cases, however, the materials may affect species other than man in quite different ways, and pronounced changes in ecosystem characteristics can follow.

The story of man the technologist is, in most respects, simply an extension of man the farmer. However, with the industrial revolution, man's ability to harness power to his needs meant that the impact of his activities on the environment increased tremendously.

To my mind this impact has two main, closely linked, aspects. The first has been the dramatic and continuing increase in man's numbers as his capacity to manipulate agricultural ecosystems for food production, and his control over human disease, have increased. The second has been the development of a great diversity of human activities, human demands, and human products. Thus not only has population itself increased rapidly but the demands of each human being for factors other than basic food needs have also increased. Man the technologist expects not merely to survive but to enjoy a socio-economic infra-structure which provides transportation, education, housing, recreational space, and many other cultural facets.

To satisfy these desires and needs, man has affected the environment both directly and indirectly. In a direct sense his mechanical activity—in constructing cities, highways, dams, and in soil cultivation and mining—is the most striking and obvious. Indirectly, though, the other products of modern technology are also of great importance as agents of change.

These products, in the main, are those of chemical and engineering technology. They include the wide variety of products needed by modern industry, agriculture, and commerce—agricultural and industrial chemicals, for example; as well as the by-products of these industries—manufacturing residues, exhaust fumes, hot water. They also include the debris of the modern consumer society—packaging materials, sewage and food wastes, detergents, worn-out and useless 'durable' consumer goods, and so on.

In these activities, man the technologist has attempted to ignore the capacities and characteristics of his ecosystem. The agricultural ecosystems in which he produces his food have been still further removed from stability. He has loaded them with the products of chemical technology thinking only of maximising food yield from a few species. In the process the nutrient and non-nutrient chemicals (fertilisers, pesticides, weedicides) which he has added have had repercussions far beyond the ecosystems to which they were applied.

Excess nutrition of agricultural fields can cause the enrichment of inland waters into which these nutrients drain. In turn, this can cause such an increase in aquatic photosynthesis that ecosystems can be completely changed. In some cases entire lakes can fill in with photosynthetic products.[11] With regard to pesticides, there are many examples of target organisms developing immunity to the substances used to kill them, yet of other species remaining susceptible. Furthermore, not only are vulnerable species directly damaged or destroyed, but many of these substances remain biologically active for lengthy periods of time, and may accumulate, particularly in food chains involving sequences of carnivorous animals, until they kill species originally unaffected (fish and birds are often affected in this way). In consequence, agricultural practices have, in some cases, endangered the ecological stability of extensive regions.

In the ecosystems in which man has built his cities, he has also

[11] K. Sperry in *Science* (1967), **158**: 351.

added vast quantities of nutrient and non-nutrient compounds—both domestic and industrial wastes. These too have affected regions far greater than the areas where these materials have been dumped.[12]

The results of these activities are all around us and I do not need to recount them. A week seldom goes by without the daily press providing examples. The stark realism of the situation is that, in the case of agriculture, I believe we are now dependent in large measure on these practices; and, in the case of our population centres, I think we have almost come to accept them as a fact of life.

The impact of these changes on the environment as a whole is now just beginning to be appreciated. Ever since his appearance on earth, man has attempted to exploit his local environment for his own ends. In a sense, all organisms have done this, whether deliberately or not. As long as man used natural methods for this exploitation, and the power of his own metabolism, and as long as his numbers were low, there was little likelihood of the changes he induced affecting more than his immediate environment—and his early attempts at exploitation were still essentially conservative, in the sense that they preserved the basic diversity and character of the environment. Now, however, the situation has gone full circle: man is so abundant and so powerful that he is changing the properties of the entire biosphere. The rate of change is far greater than occurred even during the great transitions from one geological epoch to another. Clearly this trend must be reversed.

The motivation for many of man's actions has been what Garrett Hardin has termed the philosophy of the Commons.[13] Hardin illustrates this philosophy by the following example: visualise a pasture open to all, on which a number of herdsmen are free to graze their stock. Each as an independent entrepreneur will attempt to keep as many stock as possible on this common ground.

Few problems arise until the total number of stock reaches the carrying capacity of the pasture. Then any one herdsman asks, 'What is the value to me of adding one more animal to my herd?'

His profit is related to the number and condition of his stock. He knows that the addition of one animal to the total herd on the

[12] A. M. Beeton in *Limnol. Oceanog.* (1965), **10**: 240.
[13] G. Hardin in *Science* (1968), **162**: 1244.

common will reduce the nourishment available to each by a very small fraction indeed. By comparison that animal represents a relatively large increase in the size of his own herd.

As Hardin points out 'the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another . . . But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy.'

In how many cases can we see aspects of this philosophy being acted out! The chemical manufacturer who decides that rather than clean up the effluent from his factory, it is cheaper for him to pollute a stream and pay only a share of the taxes levied by the city council to clean up the pollution so induced; or the farmer who keeps adding agricultural chemicals to increase his yield, without thought to the effect elsewhere; or even the parents, in countries with pressing population problems, who add more and more children to already large families and thereby increase the load which society as a whole must bear.

Clearly the freedom of the individual in matters affecting other people cannot continue without restraint. The last great commons are the air and the sea, yet already changes are occurring to these.

Let us look, for example, at changes which are occurring in atmospheric CO_2. The energy that man has used to power his industrial society has come primarily from the combustion of fossil fuels. You will recall that these have been laid down during geological time, and that it was largely their laying down that caused oxygen levels to rise to values which permitted man's evolution. Fortunately, consumption of these fuels is not likely directly to affect oxygen levels, at least to a significant degree, but already it has affected the level of CO_2 in the atmosphere as a whole.

The rate of combustion of these fuels is staggering—so great that it is difficult to appreciate. To put it in terms which may be more easily visualised, the amount which was used last year was equivalent, in terms of combustion, to a bush-fire which would destroy the entire vegetation of Australia.[14] Small wonder that, if present trends continue, the amount of CO_2 added to the atmosphere from fossil fuels is likely to equal the pre-industrial revolution concentration within fifty years. This CO_2 is mixed relatively rapidly into

[14] R. O. Slatyer, unpublished data.

the surface layers of the ocean so that the net effect on atmospheric concentration is only about one-half the amount added;[15] unfortunately, subsequent mixing with deep ocean waters takes periods of the order of hundreds of years, so pronounced increases in atmospheric levels are unavoidable. So far it has not been possible to calculate the likely climatic effects of these changes; suffice it to say that some estimations predict an increase of mean world temperature of several degrees.[16] Should this occur, dramatic changes in cloudiness, rainfall, and agricultural productivity, amongst other things, may take place.

What are the solutions to this collision course between man's numbers and demands on the one hand, and his environment on the other? It is clear that the goal of the 'greatest good for the greatest number' is impossible to achieve. Despite the bliss that this phrase may conjure up in some people's minds, man cannot maximise for both of these factors at once. Ecologically, it is probable he cannot maximise for either, unless the goal 'of the greatest good' is identified with conservation of his own species. But our present numbers, our present technology, and our present attitudes are not consistent with this goal. What are the requirements if man is to maximise for conservation of his species, for his place in nature?

Firstly, he must regulate his numbers. Unless population stability is achieved, everything else must ultimately fail.

Secondly, he must conserve and recycle the basic materials he uses to the greatest possible degree.

Thirdly, he must ensure that his food supply is adequate for his regulated numbers, and that the means of its production are not in themselves leading to environmental deterioration.

I believe the principle of conservation and recycling should be applied both to renewable and non-renewable resources. Consider, for example, the nutrients in domestic sewage, including food scraps as well as body wastes. At present these nutrients move from resources such as rock phosphate or atmospheric nitrogen to factories to farms to human mouths and then through sewage systems to inland waters or to the sea. There is no effective procedure to recycle these nutrients to agricultural ecosystems where they could be used again and thereby reduce the need to draw on the basic

[15] R. Revelle and H. E. Suess in *Tellus* (1957), **9**: 18.
[16] G. N. Plass in *Tellus* (1956), **8**: 140.

resources. Furthermore, sewage tends to pollute the ecosystems into which it is discharged by over-enrichment, even if not in a pathological sense.

In much the same way, metals for industry are obtained mainly by digging fresh ore out of the ground, rather than by re-using it from worn-out commodities. These non-renewable resources are not inexhaustible. Furthermore, their extraction, processing, and accumulation frequently pose problems in ecosystem stability. Although short-term, 'commons' type economics may indicate that present practices are cheaper than those which would involve resource conservation and recycling, I contend that serious attempts to reduce the cost of re-separation of primary substances from manufactured products—minerals from sewage, metals from durable consumer goods, etc.—may well make such procedures competitive with ore processing.

Similar remarks apply to energy. At present it is cheaper for us to use fossil fuel energy than energy in nature in the form of solar or tidal power. Only hydro-electric power appears to be competitive. Perhaps nuclear energy can be regarded separately, but it is clearly undesirable to continue to exploit fossil fuels purely as a source of energy. Apart from atmospheric contamination these fuels represent chemical energy which could play an important role in recyclable human food supplies. In energy terms, the fossil fuels being burnt each year would feed the present world population for twenty years. Clearly, intensive research should be directed to the harnessing of natural energy sources.

The challenge to agriculture, as I see it, is to use, as far as possible, ecological principles to nourish crops, to control pests and diseases, and to prevent erosion. Agricultural chemicals should be used with much greater care and should preferably be of a type which can be rapidly broken down and utilised in food chains. As far as possible these chemicals should be retained on each farm. In this way agricultural ecosystems would not only gain more internal stability, but the reduced degree of erosion and chemical pollution would help to minimise the risk of contaminating other areas.

Clearly there are limits to the degree to which ecological principles can be applied, for the reasons given before. To me, this suggests that consideration should be given to isolating at least some agricultural ecosystems from natural ecosystems. Already there is a trend in this direction, reflected in the increasing use of greenhouses for horticultural crops, and in the methods used for chicken and egg production. In many cases these practices are more economic than conventional agriculture and it would seem that much of our vegetable and meat production could take place in this way, thereby separating part of man's basic food chain from natural ecosystems, and enabling foodstuffs to be produced in environments where pests and diseases could be safely and easily controlled without threat to other species.

However, the main use to which agricultural land is now put is to produce food grains—our primary energy foods. The areas used for such production are so vast that controlled environment culture, or forms of foodstuff synthesis, would appear to be impracticable, at least with present or foreseeable technology. In such areas agricultural scientists must devise ways of ensuring productivity while maintaining stability. This task should not be too great as long as the pressure to maximise productivity is relaxed and the pressure to maintain ecological stability is increased.

The three main requirements which I have suggested for ecological stability and long-term human survival—control of our numbers, control of our food supply in a way that minimises the degree to which we jeopardise other species, and the recycling and conservation, as far as possible, of the materials which constitute our basic needs—all add up to living ecologically. There is no doubt in my mind that this is possible, but I realise that, in the short term, it probably makes economic nonsense.

What is required is a change in our basic philosophy—from an attitude to our environment which regards it as a resource to be exploited for short-term personal, regional, or national gain (the attitude of the 'commons') to an attitude of living ecologically in a way that is essentially conservative of the environment. Perhaps one must ask where is the true economy of economics.

I think the biologist has an important role to play in pointing out the ecological rules for this change; but the task is one for all mankind. If men of all nations can be made to see themselves, not engaged in battle against each other for a share of a commons which no longer exists, but rather as fellow members of a species which has passed from the stage of competition against other species to the infinitely more dangerous stage of competition within itself, perhaps we can really set ourselves on a new path of human progress in partnership and in harmony with our environment.

In closing let me remind you that the motto of this university is 'To know first the nature of things'. This is an admirable first step in living ecologically. To this one needs to add a guiding ethic. An appropriate phrase is inscribed on the entrance to the CSIRO Phytotron in Canberra. Despite its biblical language, the words are, I believe, those of a local and contemporary philosopher, Otto Frankel. The inscription reads, 'Cherish the earth for man will live by it forever.'

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2

Origins and Some Limitations of Human Intelligence

G. N. SEAGRIM

I WOULD like to preface this lecture with two precautionary remarks. The first is that any criticism I may appear to make of the activities of those engaged in university work applies in double measure to my own activities. In double measure because, being aware of my shortcomings, I have not been able to do anything about them. This inability to direct one's conduct on purely rational grounds is one of the limitations of human intelligence that I want to talk about. In this case I can speak with authority.

The second concerns what I have done with the ideas of the great men on whose shoulders I have attempted to climb. After I have finished with them, those ideas will probably be unrecognisable to their authors. It is a second characteristic of human intellectual activity that it can deal with information only in so far as it can be assimilated to existing structures: as the rabbit turns carrot into rabbit, so do we turn other men's wisdom into our folly. This assimilative characteristic of human thought is a biologically given limitation which is too often overlooked in our present mood of vaunting optimism.

I would like to draw your attention to the problem of what can be done about the situation depicted for us by Professor Slatyer. He presented us with a statement of account in regard to the resources of the biosphere. He discussed the ways in which humans were drawing on this account and the probable trends in investment and expenditure. He made it clear that the account is precariously balanced and that whether or not it goes into the

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'red' will depend on how well man can tailor his actions to the situation.

The general idea is that we, as a species, preferably with our present civilisation, should remain in existence. To do this we will have to draw heavily on our resources of knowledge and of intellect and, I am going to argue, on our stocks of wisdom.

For this lecture, I have set myself the more modest question of whether or not we are making wise investments of our intellectual resources. How are we using our psycho-sphere?

Let us first review the problem to see what we have to do.

I am going to take a short-term view. If we take a long-term view, the problem is quite different and all we can do is to analyse, with what detachment we can muster, the evolutionary tendencies which we alone, of all animals, can observe in ourselves. This would provide an admirable academic exercise, entirely in keeping with the activities which I shall presently be assailing. In the short term, however, I take seriously the views of Professor Slatyer and others that, on present trends, some of our vital physical resources are going to run out in a hundred years or so. The trends, therefore, have to be decelerated or reversed.

In short, we have got to be successful in three respects: we have got to make accurate predictions, we have got to formulate wise policies, and we have got to persuade our fellow men to adopt those policies.

I have no doubt that our predictions will continue to be brilliantly, if ghoulishly, successful. One prediction I am confident of making is that we cannot put the evolutionary clock back. Although the most fundamental changes that are occurring in man's estate are what Waddington calls socio-genetic,[1] they are as irreversible as the bio-genetical changes with which he compares them: there is no possibility within the selected time scale (or any other for that matter) of returning to ancestral forms of living. Unlike Tolkien's Hobbit, we cannot escape or postpone our immediate concerns by returning the Ring to the Mountain.[2] We have to continue to advance or, if you accept the notion of socio-genesis, to evolve.

[1] C. H. Waddington, *The Ethical Animal* (London, George Allen and Unwin, 1960). The terms 'bio-genetical' and 'bio-genetic' are used here to refer to what Waddington refers to as 'the biological genetic system' (p. 117).

[2] J. R. R. Tolkien, *The Lord of the Rings* (London, George Allen and Unwin, 1955).

But there is perhaps no reason why we could not practise a form of socio-genetic selection, the counterpart of bio-genetical eugenics. In fact, this may be what we will have to do. But do we know how to?

To do it, we have to alter man's conduct (conduct being understood as the overall pattern of behaviour in contrast to behaviours). There are only four ways of doing this: to dictate, to persuade, to train, or to wait for it to happen spontaneously. Some will pin their faith on one course, others on another. For my part, and perhaps for the obvious reason that I believe that men really only obey the dictates of their freely taken decisions, I would prefer to wait and see and, at the conclusion to this lecture, I will suggest that this policy is not without hope. But it will be argued that time will run out and that, in any case, the direction taken by events might be most unacceptable: surely rational decision *can* influence the course of events?

The idea that we can depend on processes of education is very attractive, and the great upsurge of the teaching of biology in schools is another hopeful sign. But here again, time is against us: it takes generations for education to affect conduct.

So we are left with persuasion, gentle or otherwise. Let us concentrate on the gentle.

There is little doubt that man is persuadable and that psychologists will eventually be able to tell us how to control his behaviours and possibly even his conduct. This is inevitable, if frightening. It is frightening, not because psychologists will do the controlling, but because their knowledge of how to do it will become generally available. We have lived through the physicist's dilemma in this respect, are entering that of the biologist, and approaching that of the psychologist. Each appears as a progressively more terrifying but nevertheless essential step in our evolution. To calm your immediate fears I add that I am not too confident that we will acquire the necessary skills soon enough. As things stand, humans and animals can be trained, persuaded, and dictated to in limited spheres and for short periods, but beyond that they remain recalcitrant.[3]

But whatever may happen in this area, in the development of techniques of persuasion, decisions are going to have to be made,

[3] K. and Marian Breland, 'The misbehaviour of organisms', *American Psychologist* (1961), **16**: 681–4.

policies decided upon, and we hope that they will be wise ones. I doubt very much if the procedures will change very much: politicians will continue to make the decisions and they will continue to do so on the advice of a limited group of experts. These men, who we hope will be a wiser group than Snow's New Men have been,[4] will of course be drawn from our most highly educated group, our university graduates. As at present, they will form an elite.[5]

What sort of people should form this elite who have got to advise on how and in what directions man must be persuaded to curb his biological nature?

In the first place, I think that they will have to *like* people. The decisions they are going to have to take will be tough but will have to be applied with humanity because humans, like other animals, respond to kindness.[6]

As scientists, they will have to be prepared to conduct research of such long duration that its results will not be known in their own lifetimes. It will be research whose terms they cannot define and whose results will not lend themselves to the usual logical tests. As a result they will have to trust their intuitions rather than logical powers, intuitions based on a deep understanding of biology, a 'feeling' for nature and a deep understanding of what Dobzhansky refers to as 'the Ultimate Concern',[7] man's purpose in nature. This will call for humility and for a wisdom beyond their times. Perhaps a greater proportion of them than at present will therefore be women!

[4] C. P. Snow, *The New Men* (London, Macmillan, 1957).

[5] The term 'elite' appears to cause some apprehension. No hereditary significance is intended but the term is being used to refer to that small band of privileged persons who, by virtue of their superior abilities, opportunities, and luck find themselves in a position of secondary power as advisers to those who really wield the power, the politicians. While the membership will undoubtedly change, I cannot imagine a situation arising, other than that of a dictatorship, in which their services will not be required.

[6] I am reminded of the story told of a visit to the laboratory of a famous 'rat' psychologist. While the great man was out of the room, the laboratory attendant confided in the visitor that, no matter what the professor thought, the fact was that the rats ran the mazes because they wanted to please him, the attendant!

[7] T. Dobzhansky, *The Biology of Ultimate Concern* (New York, New American Library, 1967). Dobzhansky attributes this felicitous term to P. Tillich, *Theology of Culture* (New York, Oxford University Press, 1959).

Are we currently selecting the right sort of people? And are we giving them the right sort of training?

We are all very worried about selection because the I.Q. seems to have failed as a predictor and far too many students are failing at university. In its place the present fashion seems to be for 'creativity' with a dash, more or less, of convergent and divergent thinking.[8] This ideal is based, of course, on the image of the present successful man, of whatever calling, and considerable efforts are being organised around the tracking down of this elusive quarry as early in life as possible. I suspect that he may long remain elusive, like T. H. White's wonderful creation, the Questing Beast.[9] As this mythical beast was optimistically and irrationally hunted by King Pellinore and his stupid Brachet, so will creativity be hunted by psycho-metricians and their computers. Like King Pellinore, they do not know if it will live up to their expectations when cornered. In the meantime they make do with such fewmets of doubtful origin as they find by the wayside. These they examine excitedly and, just in case, cram into the children: who knows, they may contain the seeds of creative genius. Perhaps we shall have the 'creativity pill' to be taken by young women when the time is, so to speak, ripe for them to go off *the* pill. But creativity about what?

About the furtherance of knowledge, the aim of all university training, of course. In other words, an extension, at an accelerated rate, of what we have been doing for the last few centuries. After all, it has worked wonders for man's estate. But in the absence of advocates for alternatives, and in the face of academic conservatism than which there is none greater, the question must be asked at this point in history of whether this activity, as at present practised, is appropriate to our needs for a wise and humane elite? Let us look at the activity in some detail.

To understand it, we need to consider the evolution of intelligence because, of course, the people practising this activity, our present elite, are the intelligent, by elusive definition and, of course, it did evolve and must therefore still stand on some fundamental biological mechanisms. We must understand these even if this sort of inquiry is unfashionable and is regarded as unwarrantably pessimistic.

[8] L. Hudson, *Contrary Imaginations* (London, Pelican Books, 1966).
[9] T. H. White, *The Sword in the Stone* (London, Collins, 1958).

The direction taken by the evolution which led to man's intelligence is, of course, marked by a progressive freeing of the species from the dictatorial here-and-now control of the environment. Gene mutations as sources of change gradually gave way to individual trial-and-success, bio-genetic selection to socio-genetic adaption; physiological homeostatic mechanisms were gradually supplemented and protected by intelligent foresight; real action was largely replaced and supplemented by interiorised action, which we call 'thinking'. But while the emphasis in regard to what is transmitted from generation to generation has been shifted from bio-genetic processes to socio-genetic ones, the way in which the information is transmitted, involving the mechanisms of learning, of intelligence and of thinking, itself has its roots deeply embedded in bio-genetic forms. This bio-genetic origin of our highest achievements has tended to be forgotten in the behaviouristic age from which we are just emerging and consequently some of our limitations as rational beings have appeared to be inexplicable. And the inexplicable is frightening and provokes aggression.

As the system by which we come to know has its roots in biological processes, we must expect it to exhibit certain biological characteristics. I want to mention three of these.

The first is that the system matures. Just as most animals require time and experience to tolerate their ultimate diets, so does it take time and experience for the full functioning of the intellect to develop. Jean Piaget, too well known to require introduction, has made this analogy explicit.[10] Just as all organisms take in nutrients and work upon them in ways which are innately given, to convert them into body tissues; as the behaving animal moves about in and acts upon his world, structuring it to his innate needs in terms of neural patterns of stimulus and response sequences whose laws are innately given, so does the thinking animal interiorise a representation of his acted-upon world according to certain principles. In each case there is a give and take, an assimilation of what is taken in to the existing structures and an accommodation

[10] J. Piaget, a Swiss, first trained as a zoologist and then, within the context of adaptation, turned his attention to thought processes. He has been publishing in this area since 1921. A brief autobiography may be found in *A History of Psychology in Autobiography*, Vol. IV, ed. C. Murchison and E. G. Boring (Worcester, Mass., Clark University Press, 1952). The most concise summary of his position is probably to be found in *The Psychology of Intelligence* (London, Routledge and Kegan Paul, 1950).

of the latter: the animal grows, learns, comes to know. In a word, changes or adapts.

And our educators notwithstanding, ready-made knowledge is indigestible in the early years. The child has to pass through what at present appears to be well-marked stages in the process of personal adaptation, stages of successive integration extending over not less than twelve years. Each stage is built up on the constructions of the previous one and differs from it in what can be assimilated. Knowledge, like bodily tissue, has to be built up by the child's own innate processes working on his personal experiences, at his own rate. There are no obvious short cuts.

The stages which Piaget has described are exclusively concerned with the development of logical thinking in the sense of deductive reasoning, and Piaget has paid much less attention to induction and to intuitional processes. Far too little is known about these and, as a result of Piaget's growing popularity, and for other reasons to be discussed later, there is a great danger that the logico-mathematical processes by which we come to know the physical universe may be, are in fact, over-estimated, over-emphasised. While Piaget does describe a pre-operational, intuitive stage (during which the child is often surprisingly successful only to become less so for a period while he, so to speak, *tries* to think logically) there is little doubt that this early form of reasoning is actively discouraged or even ruthlessly eliminated by our training procedures. I do not, of course, wish to suggest that deductive powers should be discouraged. On the contrary, the better the logical structure, the sounder will be the intuition: you get a 'feel' for your subject. But my plea, if you wish, is that the intuitive process should not be strangled at birth, should not be starved of exercise, because I believe that after Piaget's final stage of formal logico-mathematical thinking there lies one more, so brilliantly evident in his own work, in which the marrying of logic and feeling leads to successful intuition. Moreover it is obvious that all biological adaptation is inductive.

There are almost certainly critical periods in the development of various thinking forms, as there are in the development of many other biological functions. And the best way to prevent or to delay the development of a potential skill such as inductive thinking is to force-feed its competitors and thus to create massive barriers of habit. Too much deduction may abort intuition.

It is this habitual nature of thinking that I want to single out as its second biological characteristic. Thinking has quite rightly been likened to a skill and, like all skills, it is subject to habitual limitations the subtleties of which, in this case, are little understood but which it would be unwise to ignore. The habitual restraints apply both to the forms of thought preferred, as pointed out above, and to their content. As Piaget has pointed out, successful adaptation depends upon a balance (he uses the term 'equilibrium') between assimilation and accommodation, and a less healthy state of affairs exists when the assimilative tendencies are over-emphasised, when there is too great a tendency to absorb the unfamiliar into the familiar. Pressures towards excessive assimilation exist whenever you have a body of shared knowledge, what we call 'facts', which are socially transmitted by verbal means: inconvenient events are either rejected or twisted, theories are irrationally defended. The histories of science are so full of examples that I need not quote them.[11] Linguistic forms themselves may emphasise assimilative tendencies, but I am sure that our insistence, in university science teaching for example, on hypothetico-deductive reasoning, and on the acceptance of text-book facts, at best weakens the student's confidence in his intuitions and inhibits his accommodative tendencies. At worst, it substitutes rigor mortis for intellectual rigour, in which process the coffin-nailer's role is taken by the Ph.D. which encourages students to find a topic on which to exercise their hardening skills rather than to wrestle manfully with problems.[12]

A third aspect of the system which is surely bio-genetically determined is that it is self-motivating: our thoughts like to exercise themselves. One is reminded here of an event which Konrad Lorenz aptly described as 'vacuum activity':[13] the tendency for an animal's innate action patterns to emerge spontaneously, in

[11] Some interesting examples are to be found in: J. Needham, *A History of Embryology*, 2nd ed. (London, Cambridge University Press, 1959) and A. Koestler, *The Sleepwalkers* (London, Hutchinson, 1959). Lavoisier is quoted (see L. M. Hurvich, 'Hering and the scientific establishment', *American Psychologist* (1969), **24** (5): 497–514) as having said, in 1785: 'The human mind gets creased into a way of seeing things. Those who have envisaged nature according to a certain point of view during much of their career rise only with difficulty to new ideas.' Plus que ça change!

[12] See D. T. Campbell, 'Methodological suggestions from a comparative psychology of knowledge process', *Inquiry* (1959), **2**: 166.

[13] K. Lorenz, *Evolution and the Control of Behaviour* (London, Methuen, 1966).

the absence of the usual releasing stimulus. As our thoughts are interiorised actions, it is not surprising that they should thus exercise themselves spontaneously and, almost certainly, unconsciously. By this process a great deal of sorting out is done, inconsistencies are ironed out. Our thoughts become more adequate representatives of our environments and the latter present fewer and fewer surprises. This is obviously an interiorisation of biological adaptation and one that is greatly assisted and accelerated by linguistic communication.

But as Lorenz pointed out, vacuum activity is characteristic of the caged animal. It is not surprising, therefore, that our intellectual elite, caged as it is, albeit in a gilded cage, should exhibit this interiorised abstract activity to a marked degree. In fact, it seems to me that the great emphasis in our university training is towards this interiorised activity for its own sake and that, as a result, much, perhaps far too much modern science, arts, medicine, law, and economics are about this. In fact, our highest mental achievements have largely become a form of interiorised play.[14]

This vacuum activity, of great sophistication, extremely rewarding, extremely useful materially, is indeed to be compared with games playing and the men who are successful at it with men who are good at games. They seem to be indistinguishable. Both are highly skilled, train hard for years, love their 'work' and public acclaim. They wear special uniforms, command enormous fees, and tend to be self-centred. They are healthy and, within rather broad limits, ruthless opportunists, as Watson makes clear in *The Double Helix*. They strive to establish world records and justify their activities in terms of what the public wants: anyway, it's the game that counts. So prestigeful, so newsworthy, and so remunerative are their activities that we parents, child-sellers that we are,[15] all hope that our children, too, will be successful.

The shocking thing, of course, is that this sort of activity is so

[14] Piaget has described the way in which the child's rules of the game of marbles develop and change with age. See *The Moral Judgments of the Child* (New York, Harcourt, 1932). However, these rules are definitely 'of the game' and appear to me to be of convenience rather than of ethic.
[15] This remark is a play on Hersey's title *The Child Buyer* (Penguin Books, 1960). In that book he describes the ambivalence felt by parents and civic authorities when an industrial talent scout wants to buy a precocious child. I think that parents very generally behave as if they wanted their children to be desirable commodities although, of course, the idea that this might be so would horrify them.

monumentally lacking in concern for its consequences.

This running riot of the intellect is, I believe, an unexpected by-product of man's increasing cleverness. As his developing cleverness absolved him, personally, from that brutal contact with the earth that is the lot of those who hunt for and gather food and build shelters, and as he was absolved, personally, from killing and from observing death, destitution and famine, he could divorce his work from reality, he could retreat into the cage of his own making. His work became play, at an increasingly high level and for increasingly high stakes. He rose to the equivalent status of the nobility and, in place of sending his armies to acquire new territories, he sent forth his word to do the same. Professor de Solla Price, lecturing in this university recently, doubted if Nero did fiddle while Rome burned, but future historians will be forgiven if they liken our lack of attention to the ultimate concern to the greatest stringed orchestra ever assembled and playing against a backdrop of pyrotechnics of cosmic proportions. I would like to be around in 200 years' time when this phase of intellectual activity is being assessed in terms of man's evolution.

No doubt the phase has been an essential one in our advance, and not a false lead. It has, of course, greatly accelerated the rate of change. As one of my colleagues who has come somewhat under the American influence puts it, the technological spin-off has been colossal. It has released an unprecedented acceleration in social change whose consequences, for lack of timely concern, we are unable to predict and whose course we cannot control.

But while full credit must be given where it is due, in this case to the physical scientists and technologists, there does come a time when we have to stop clapping, when we have to become more critical of the performance. And I wonder if we have not reached that point? Can we expect the kind of wisdom I say we require from people trained in this way?

I do not wish to imply that our present breeds of successful men are unethical, immoral, or amoral. In their personal lives they are rather like the rest of us: those on the Arts side a bit flighty perhaps, and those on the Science side a bit stodgy. Nor do I want to claim that their work is anti-ethical. But I do want to make the point that their work-play is quite devoid, or almost so, of all reference to ethical considerations and that, in this respect, our successful academic suffers from as profound a double morality as that which he descries and decries in the successful businessman.

This, of course, does not prevent him (and other quite insignificant academics too, as this lecture demonstrates) from making weighty public pronouncements on ethical issues! He usually does this when he has become too old to lead the tribe, whose youngsters are not greatly impressed. His status in the tribe, biologically speaking, is then rather like that of the elderly ape who, though weak, is not destroyed or driven out by the young males, but is tolerated, perhaps out of habit, or at best because he knows some good drinking places and is good at stopping fights.

But surely people trained on this model could not meet our new requirements, of being wise leaders in the biological crisis in which we find ourselves? Surely our new men and women will have to be in touch, from the very beginning of their work, with ethical issues? Our survival will depend on their ability to take our evolution on to the next stage, which must be the wise application of the explosive and dread powers released and yet to be released by the scientific revolution. They will require this wisdom before they reach senescence and, no doubt at all, it will direct their life's work into new channels requiring new ways of thinking, new notions of what it is to be successful.

It is a nice question whether these people need also be personally moral or deeply ethical. I think it may be foolish to suppose that this is possible. Whether or not we take Koestler's image of man's schizophysiology seriously,[16] it is incontrovertible that there still exists a fundamental disharmony between his instinctual nature and his rationality. I do not share Koestler's optimism about the possibility of a psychopharmacological self-repair job being effective in the near and useful future, and I suspect that we must allow our new men and women an irrational streak, an area of behaviour which we, by our present standards, would regard as wanton or immoral. I suspect that they may turn out to be more ethical in their work than in their personal lives.

I have been conducting this discussion on the assumption that some sort of sociological eugenics might be possible, as if we were going to bring about this step in our evolution consciously. But of course we would not have the slightest idea of how to do it. We know next to nothing, largely because of our incredible neglect in studying our own biological nature, about the development of ethic,

[16] Koestler, *The Ghost in the Machine* (London, Hutchinson, 1967).

except that it takes place on or at the mother's knee. As such, the processes of its formation are unconsciously and massively protected from direct examination by all that 'weird gallery of monsters' unearthed and described by Freud.[17] Its observation is made very much more difficult now by our present tendency to bring up our children in secret. The only worthwhile and timely attempt to overcome this restriction, the Peckham experiment,[18] was starved out of existence by an elite which had been reared on a diet of cataclysmically successful physical sciences and which could not advise an ignorant government to support research to which no term could be set, from which no material gain could be expected.

We get a glimpse of what we would be up against if we consider the outcomes of two systems of child rearing which have led to forms of ethical pathology. I refer on the one hand to the Australian Aboriginal tribal upbringing and on the other to our own Western upbringing. The former appears to produce a loyalty to tribal mores which makes the children almost completely impervious to all attempts by even the most devoted and skilled teachers to get them to learn even the rudiments of the scholastic skills they are going to require if they are to take their place in our Western culture.[19] It appears to have bred a 'negative-push' or an 'anti-motive' of extraordinary strength, one which makes naught of these deeply ethical beings when they come up against our culture and one which is completely antithetical to all our notions of what it takes to be successful. Albeit, the upbringing is gentle and permissive.

Our own secret and personal upbringing has, for its part, given

[17] W. McDougall, *Social Psychology*, 14th ed. (London, Methuen, 1919).

[18] The Peckham experiment was a very long-term longitudinal investigation into the problem of health, using humans as subjects. It is described in several books, amongst them *Biologists in Search of Material* (London, Faber and Faber, 1947), written by G. K. Scott Williamson and Innes H. Pearse, the co-directors of the experiment. It commenced in 1926 and was finally brought to an end, with the introduction of the National Health Scheme, in 1950. It was conducted at the Pioneer Health Centre, Peckham, London.

[19] Perhaps the Aboriginal has a superabundance of what Waddington calls the 'Authority bearing systems of the mind'. An alternative explanation would be that he does not differ from other peoples in this respect, but that his society has discovered very effective means of reinforcing these systems. If so, the process must occur very early in life because the Aboriginal school child does not appear to be able to accept the new authority.

rise to a super-ego ridden ethic which carries with it explosive repercussions. There is obviously more than a chance relationship between the isolation of the family from the group and what I have labelled vacuum thinking. The thinking has had to be divorced from the personal feelings, Hudson suggesting, for instance, that emotional insecurity *drives* the individual into this encapsulated unthreatening occupation.[20]

We are therefore, in our psycho-sphere, as in our bio-sphere, in a delicately poised situation in which too many wrong decisions may lead to an irreversible collision course with catastrophe. We are in an incomparably weaker position to predict and to control than the bio-physicists are;[21] and we are certainly in no better position than they to persuade man to adopt wise measures when these infringe on his biological liberties and when their gains are not his but for future, unborn, generations.

However, such pessimism as I have, in spite of my best efforts, allowed to creep in may, I hope, be somewhat dispelled when I conclude on a note of high optimism. I detect in our new men (is this Snow's Third Culture?),[22] in our students and in our school children, the emergence of an ethical concern, a wisdom about the ultimate concern, a humanity and a humility, international in reference and in scope, new and exciting. Some think it is accompanied by quite unacceptably low standards of personal ethics or morality, but I doubt if this reaction is much more than the usual reaction of the older generation against their successors.

Goodness knows where this awakening of concern comes from, but no doubt it explains the present drift away from the physical sciences, in which we have perhaps invested enough for the time being. No doubt it will demand a new academic environment conducive to its wellbeing, and while it may not produce the spectacular and explosive successes of its evolutionary predecessor, it will be more obviously relevant—it is welcome and timely. Let us not strangle it at birth just because we cannot assimilate its message to our existing thought and ethical structures. It may be our last hope.

[20] Hudson, *Contrary Imaginations.*
[21] It was interesting to listen to a recent broadcast discussion of the possible military uses of hurricanes. The speaker commented that before we could control hurricanes we must understand their behaviour!
[22] Snow, *The Two Cultures and a Second Look* (London, Cambridge University Press, 1965), pp. 70–1.

3

Disease and Diversity

EARLE HACKETT

ONCE I had a medical training: that extraordinary blend of science, empirical information, character conditioning, and lack of sleep. I am a qualified doctor; I am licensed to practise applied human biology. And so, I suppose, to talk about it.

But I claim no exclusive rights. I would say that every owner of a human body is an applied human biologist. Has to be. Owner-driver. So that includes everyone here.

However, in this series of lectures Professor Slatyer has spoken about the constraints of the earth, Professor Seagrim has dealt with the constraints of the human intelligence, and I am the one who is to talk of cells and organs and tissues and genes and serum and disease, because that is Medicine, and it happens to be an area where at present it is easy, even tempting, to present the New Biology as a terrifying threat.

For instance, grafting—grafting that really takes—would seem to be just around the corner. So is (though not quite so near) deep freezing and ageless preservation of the body in liquid nitrogen. And the implantation of identical fertilised human egg-cells so that from volunteer women we could raise many duplicates of notable humans—go on having copies of the same successful Prime Minister for several hundred years if you wish (do I detect a rustle of interest?). Substantial mood control by drug treatment is already possible. So is the production of artificial viruses. So are chemical and biological war weapons directed specifically at the human body.

Now when I say it is tempting to present the New Biology like that, I mean it is personally childishly tempting to me. In fact, I

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would use my privilege of lecturing to you to work off some of my personal neurotic anxiety-driven aggressiveness by threatening you with applied biology, and making you anxious. This does not mean you would not be interested in it—curiously, one is usually interested in frightening stuff, and that is why books with titles about naked apes and biological time bombs and territorial imperatives are effective (and important) vehicles of popular information, but one wishes that there were other effective ways of bringing scientific knowledge, and even international news, to the general population other than by lacing them with fear and anxiety.

The trouble is it is often assumed that because something technological *can* be done (grafting, babies in test tubes, genetic engineering, etc. etc. etc.) then it will (or should) be adopted generally and without making distinctions. In fact this very seldom happens. Within our communities we usually do make distinctions, the matter becomes particular rather than general, and the question 'Who will be the better for it?' is, in the end, answered.

Another fear we have of much biological technology is that if applied it will de-humanise. I want to be me, make my own love, breed my own children, wave my own arms, think my own thoughts.

Now—and here is the good news—the New Biology is very reassuring about this. It strongly endorses, as I will explain, the necessity for human beings to have personal and unique individual biological identities. So straight away I can say that I would strongly condemn any plan or suggestion that notable (or any) human beings (even successful Prime Ministers) should be replicated by the techniques of applied reproductive biology.

Since Hippocrates it has been orthodox medical teaching that people have different constitutions or tempers but the number of distinguishable types of human bodily constitution has been taken for medical purposes to be fairly small—maybe something like four or eight or at most a couple of dozen.

Sir Thomas Browne, that seventeenth-century English doctor who used to puzzle over things in an engaging and literary way, wrote in his book *The Religion of a Physician*: 'It is the common wonder of all men, how among so many millions of faces, there should be none alike.' He said also, you will remember: 'We carry within us the wonders we seek without us. There is all Africa and her prodigies in us.'

It may seem trite to remark that it takes all kinds to make a world, *tot homines tot sententiae*, that we are 'none alike'. But this observation of Sir Thomas Browne, and of every intelligent person who has ever lived, is one of the most fundamental biological remarks you can make. Often we do not sense the new significance of old familiar saws until they are linked with the broadening scientific culture, the new basis of our world-view. 'Water finds its own level'; 'Nature abhors a vacuum': these had merely the quality of well-tested old proverbs until they came to be understood in terms of gravitation and the behaviour of gas molecules.

Why are we all different? Perhaps you will say it is so that we may recognise one another in our community without confusion. But then I can tell you that other animal species manage to discriminate much more satisfactorily between fellows by simple combinations of colour markings or of odours. It would be possible in fact to 'recognise' as many fellows as you need to 'recognise' in your ordinary life with only a few variable body signs, quite apart from the fact that since we became intelligent animals we have been quite capable of sticking notices and badges and numbers and characteristic clothing on one another for individual identification, and we do it.

When, further, I point out to you that this question of being different is not just skin deep, it goes right down below the finger prints to the molecules of which we are made, to the genes and enzymes and proteins, then you will realise that it must be more than a matter of identifying one another by surface features, for each one of us to the very marrow is unique in the world—except for an identical twin—a unique piece of biological patterned organisation.

Charles Darwin made the biology of man continuous with the biology of animals at the whole body behavioural level. The New Biology began when it was clear that the properties of human living matter were continuous not only with those of other living things but also with non-living matter. Chemists characterised non-living matter and then became biochemists as they elucidated the structures of increasingly complex body substances, starting with urea, then on through simple sugars and fats to vitamins, hormones, proteins. Now vitamin B_{12}, insulin, haemoglobin, and of course the famous double helix deoxyribo-nucleic acid (DNA) are all characterised chemically, molecularly, and atomically.

Those sciences whose data derive for the most part directly from the molecules and atoms have got, you will probably agree, the greatest universality in human culture. American physics makes a rocket that goes to the moon. So does Russian physics. Both physicses (what an interesting plural!) are largely based on the properties of the fundamental particles. But Russian and American psychology, or anthropology, or history, or biography (to take human studies of man and his experiences not yet linked to the properties of the fundamental particles) have not such good fits one with another. They are sectarian activities.

Now I think an important aspect of the New Biology is that because it is particle-based it can (like physics and chemistry) have only one internationally valid version. And this makes it very interesting because it is the first science which includes man as one of its legitimate objects of study to have reached this stage.

However, the extension of unified particle-based science into the field of applied human biology has its special difficulties. You see, physics and chemistry have not been subjects that have seriously concerned our cultural notions of ourselves. They scarcely threatened such concepts at all when they got off to a fresh world-view in the seventeenth century. They remoulded our ideas about externals. And after some Church opposition, nobody minded. Now no rival systems bother their modern orthodoxies. Their terminologies, for instance, are new. By contrast, the New Biology has still to contend culturally with the biologies (including the biological terminologies) of Moses, Aristotle, and the alchemists, which survive alongside it today as popular traditions, still influencing attitudes and politics.

The whole dead weight of humanity is made up of 'owner-drivers', of applied biologists directing the living organisms which are themselves. Consequently a very high degree of proof and repeated demonstration will be required before generalisations from the New Biology will be accepted as verified by all concerned.

Knowledge generally applicable to human eating, learning, loving, mating, ailing, fighting and so on will probably have to pass almost the total consensus of opinion in each community before becoming operational. In contrast the physics of flight or television or the chemistry of dyes or plastics, for instance, are accepted and applied within a decade or two of passing the checkpoint of a handful of specialised scientists and technologists.

At first sight this may seem depressing to the scientific humanist. But it must be remembered that our notions about ourselves (rather than our notions about the world outside us) form a very large part of what is called the 'humane tradition' in our culture, and this amounts to a highly developed social and personal organ for human survival. We cannot expect it, even though it is self-conscious, to be modified in a flash, like a piece of chemical technology. Indeed, even the non-biological sciences such as physics and chemistry may yet find that their bridges with the broad humane process are too weak, that they may have to remain permanent mandarin activities enclosed in cultural reservations poorly related to the general experience of mankind. This may not matter, but we cannot let it happen to biology if we want to use it as a humane science. So if we can agree that the New Biology has a better relation to humanity and to the rest of reality than have any of the medieval or ancient systems which the non-scientific part of our culture has largely been presuming up to now, then we must also agree that this is now the biology which must become a classic part of everyday education—classic in the sense that mathematics and history and languages were once classic, for biology, it is now beginning to be seen, is at the base.

So Man and the New Biology is for me a world-view of Molecular Man; not Frozen Man, Grafted Man, Artificial Man, Eugenic Man, De-sexed Man, or Man Grown from Cuttings.

The first clues to the molecular difference between humans came from the blood groups. At the beginning of this century Karl Landsteiner and then others found that there are three inherited factors which, being present in particular combinations on the surfaces of human red blood cells, have enabled everyone in the world (except a few very rare mutants) to be classified into one of six groups. These were the well-known ABO blood groups. The simple point about them is that you cannot inherit all three ABO characters, no matter who you are, because the particular bit of your inheritance code that is devoted to these ABO characters has only room for two. You get one from mum, one from dad. So you can have two As, or two Bs or two Os, or an A and a B, or an A and an O, or a B and an O. So you can be straight A in double dose, or straight B, or straight O, or a combination half of one and half of another. These ABO characters are variations in the structure of a sugar molecule present on the surfaces of one's red cells.

Now didn't Darwin's doctrine of Evolution produce the idea that if two varieties of a plant or animal are in a given situation and one variety is fitter than the other in that situation, then the more fit variety will flourish and the less fit will die out as the years and the generations go by? The apes also have ABO blood groups, though in less variety than we, so there has probably been plenty of time, say 10 million years, for natural selection to play on our inherited ABO blood group molecules if one kind is more advantageous than another. So why has the whole human species not evolved towards having just that blood group? Or are we to suppose that such characters have no evolutionary significance at all so that they just vary in an idle way? If that were so, would not the first mutation towards either replacement by a basic non-varying substitute blood group substance, or towards complete absence of ABO blood groups (and deletion of blood groups by mutation can occur) result in an individual who was more fit than any of the others because he was not burdened with genetic irrelevancies, and so then should not the evolutionary process eliminate ABO groups if they are evolutionarily meaningless?

But it has not happened. Well then, if the ABO substances have natural advantages, what are they? Actually we know more about the disadvantages, which is the way of Medicine, but then disadvantage for one group is advantage for the other, in evolutionary terms, is it not?

People of group A, for instance, are a little bit more likely to get cancer of the stomach or pernicious anaemia. People of group O are a little bit more likely to get duodenal ulcer. There are other associations of the kind. Therefore in a part of the world where there are factors in the diet which promote both cancer of the stomach and peptic ulcer we should expect to get after some hundreds of generations an elimination of group A and group O leaving only Bs. Now there are indeed some areas of the world where at present people seem to be more likely to get cancer of the stomach or peptic ulcer. But these are not areas where group A or group O have been eliminated, or are even noticeably infrequent. Of course the period over which modern (or even ancient and modern) medicine has observed disease is very short compared to the period needed for a significant evolutionary change in a long-generation-time animal like man. The environmental characteristics (whatever they are) that promote excessive cancer of the stomach today in, say, Japan, or excessive duodenal ulcer in, say, a city of the West, may not have been present for more than, say, four generations. But the period we are talking about in evolutionary terms is that which it has taken us to move from apes to men, say 10 million years or 400,000 generations. In that time the earth's environment has changed a lot. Particularly in the last million, when man has lived through three ice ages and three periods of intervening warmth like the present. And since he picked up his first stone weapon and shouted his first words to his friends he has been eating new foods, encountering new viruses and parasites and bugs, spreading out, trying new life patterns and social relationships and community structures and religions.

From that first day he has been changing his environment so that even a stone age tribe might know a hundred, a thousand, different environments over the same period that their remote simian forest-bound ancestors knew only one or two. And by the time you add fire and clothing and metal and flocks and tillage, so that man himself begins to change the general surface of the earth, you can see that, as a species, a travelling, bad weather, inquisitive, interfering species, we have dealt, in short time compared to our generation times, with multitudes of different environments. We are different from a plant species which grows on only one kind of soil, or from a bird species which lives on only one kind of food, or from a fish which inhabits only one part of the sea, and so on. But man—we been everywhere, man, as the song says.

Now is it that we are genetically and molecularly diverse, one from another, because local evolutionary pressures cannot work on us any more for long enough to make us uniform because we move about so much, or is it that various local evolutionary pressures are working on us all the more and are making us diverse?

Back to the blood groups. There are, apart from the ABO groups, twelve other blood group systems which indicate molecular differences between the red blood cells of different individuals in just the same way as the ABO groups. Each of these blood group systems is inherited and assorted independently because they are each controlled by a different part of our genetic information ribbon. Some, like the Rhesus blood group system, have a dozen or more subcategories, giving very many more different combinations of pairs than those of the ABO system. Thus you can see that if we take all these blood group systems and if all their variations are reasonably frequent, the permutations add up to a high likelihood of finding some blood group difference between any two human individuals. But there is more to human blood than red cells. The plasma contains numerous soluble proteins. Some are antibodies, for example, and some are specific molecular transporters of metallic atoms like iron or copper. Now many of these plasma proteins are known also to exist, like the blood groups, in a variety of different molecular forms, all controlled by genetic inheritance. This further increases our capability to specify human diversity in physicochemical terms from the examination of blood alone.

Of course the handy thing about blood, from the laboratory viewpoint, is that it is such a convenient body sample. The solid tissues and organs tend to spill their characteristic molecular products into the circulating blood which bathes them, and they receive their food supplies and chemical signals through it.

Now, an enzyme is a very characteristic protein substance that is manufactured by cells. This is done under the very direct control of the genetic mechanism. There are thousands of different enzymes in the body and the blood is a happy hunting ground for their isolation and identification.

Without enzymes there would be no life, for none of the unlikely chemistry that builds tissues and organs against the stream of random non-living chemical action would proceed rapidly enough to get anywhere without enzymes.

Enzymes are the cogs and gears in the machine of the human body. Let us pursue that analogy. Consider a small cog wheel in a gear system and the kinds of variations one might make by altering it. By having a larger or smaller or zero number of teeth on the cog the rate of transmission of activity through the system will be decreased or increased or stopped. By being made of softer or of harder wearing material the rate at which the cog or the gear has to be repaired or replaced will affect the use of the general machine. By being responsive or unresponsive to a brake or other inhibitor, or to, say, lack of oiling, the capability of the general machine to be controlled through that cog will vary.

Now when I tell you that three-quarters of the enzymes from the blood stream which have been examined show the same sort of variations as blood group molecules, you will realise that the cog analogy is a good one. We are all slightly different chemical machines. For instance, taking only eight different enzymes in an English population it is possible to show that the most frequent combination of genetically determined types occurs only in one person in fifty. Add to that, now, the other plasma proteins, the haemoglobins, and the blood groups and although you are probably using in that little lot only one-ten-thousandth of the genetically determined items actually involved in the molecular behaviour of a human body, you already have possible permutations greater than the number of the human population of the world, which is a large number of unique chemical machines.

Now once again, what genetic and environmental situation could bring this about? Remember the ABO blood group characters again. I said you got one from mum and one from dad—so that you can inherit two As or two Bs or two Os, or an A and a B or an O and a B, or an O and an A.

Suppose there are three different environments X, Y, and Z. Suppose that in environment X it is generally a greater advantage to be A than B or O, and that in environment Y it is a greater advantage to be O than B or A, and that in environment Z it is a greater advantage to be B than O or A. Then in environment X it will be extra good to be a double A (AA), and bad from a Darwinian point of view to be a double B or a double O. Correspondingly, in environment Y it will be the Os that will have the survival advantage and the Bs and As that will eventually be eliminated if the environment remains the same and the situation is unchanged for a very long time. And in Z the Os and As will cop it compared to the Bs.

But suppose—and this is it—suppose your tribe for thousands of years spends most of the summer in environment X and all the winter in environment Y but always goes for the Christmas holidays to environment Z. Then the people in the tribe who will be at a survival advantage will be those who can make the best of as many of these environmental worlds as possible.

It will be fine to be a BB at Christmas, but better still to be an AB for then you have both A for the summer and B for Christmas to give you the best out of at any rate two of your three environments. The best, as they say, of both worlds.

So when apeman becomes travelling apeman there can be survival advantages in being a heterozygote, an AB, or an AO, or an OB. And with a differential survival of heterozygotes this tends to select for a balance of genes in the population rather than an elimination of all except one—a balanced polymorphism as it is called. And it seems very likely that it is all the changing environments we have been experiencing as apeman and human populations in the past 5 or 10 million years, particularly in the Pleistocene, that have given us all these madly polymorphic blood groups, protein, enzymes, and so on, a few of which make us look different because they affect our external appearance, but most of which determine invisible chemical differences in the cells and juices. But not only did we acquire this diversity; it is also clear (to me anyway) that having acquired the diversity we were then able as a species to face the exponentially greater rate of change in environment which began when we started to practise what we called civilisation. The bizarre and rapid molecular variations that this produces in our environment could be handled biologically only by a species with a fantastic amount of inbuilt diversity in its individuals, such that there are always some readymade bizarre types to handle what turns up. Having appeared, such diversity maintains itself, up to a point. What I will say now is we must continue to go with this, not against it. When we react with the environment we seldom do so grossly, but commonly at the chemical invisible molecular level. At this level the environment is very variable. There is a popular notion that man has controlled his environment. But we have done nothing of the kind. We are capable of changing it for ourselves almost every day, and often do. We eat a new food. Our digestive enzymes, if we have the right ones, break it down to its molecules. There are foods which some people cannot digest for lack of the right enzymes. After digestion we chemically manipulate and reutilise the food molecules to make our 'own' bits and pieces. Some people are unable to do this as completely as others because of genetic differences in enzyme make-up. So the new food does not suit them, but it suits others. And other foods suit them.

We suddenly see a new neighbour. His behaviour angers us, perhaps because we have inherited a pattern of enzymes in our central nervous system that makes us extra aggressive in our responses to the unfamiliar. Maybe this in turn affects the chemical secretions of our pituitary gland, which in turn affects other glands, which put out other chemical substances to which our small blood vessels respond by contracting so that our blood pressure rises so that our hearts cannot keep on pumping so that we die of a heart attack. Every one of these stages is chemically mediated by substances under genetic control, so that no two people may react in just the same way (except for identical twins), although most of us are not unduly angered by new neighbours!

It is the same when we respond to infection by a germ, or to a chemical poison, or to a radioactive substance, or to physical stress, or to ageing, or to a life situation from which something can be learned. In every case the fundamental response is chemical, mediated through the inherited combinations of molecules, or at least strongly influenced by them, so that individual responses vary.

Now, mostly, these responses are adequate. They preserve, as we say, the 'health' of the individual in whom they occur. They have done this for sufficient numbers of our species in the past for us all to be here today. But to any given environmental situation there is a scatter of response patterns among all the humans in a community because of the scatter of molecular patterns from one individual to another.

So although most individual responses are adequate in survival terms, there are, at opposite ends of the distribution, on the one hand the very good responses and on the other the very poor. These last do not preserve 'health' and this is ordinarily shown by symptoms or signs of biological ineffectiveness—in fact the unlucky owners of such responses are 'diseased'. Disease then is individual human life at the limits of its capacity to react to its environment.

But next week, or next year, or next millionth year, change the environment and a different lot of variable humanity will be 'diseased'. So somebody will always be sick, unless—but I'll come to that in a minute.

Now, do not think I am talking only about what medicos traditionally call 'inherited' disease—like haemophilia, or muscular dystrophy, or sickle cell anaemia, or like conditions which are very obviously inherited because their effects are caused by single genes that have marked effects. I am talking about serious disease in general, because its impact and its progress and its severity are greatly influenced by general genetic constitution.

Symptoms and suffering can be alleviated, but some people are always going to be unfit. This biological explanation answers one of the puzzling questions of antiquity—why are the gods so cruel and arbitrary as to send disease more severely to certain communities or to certain men, and not to others? Is it to punish them? Are they sinning? The answer is that those who are dangerously sick are usually bearing the local burden of the essential evolutionary process. If those who are not sick will grasp this idea they can see that its logical extension into social or 'moral' behaviour requires that they, the healthy, should be grateful to those who are diseased or in pain, who are often a living indication of an effective evolutionary mechanism by which the whole human community is surviving.

I think Biological Man should not in any way stop trying to alleviate the effects of disease when it occurs in individuals. It is sometimes suggested that modern medicine is increasing the 'genetic load' of unfavourable genes carried by humanity. This I think is nonsense. That genetic load is our essential species equipment. A gene combination which is unfavourable today may turn out to be favourable tomorrow, either as it is, or re-combined with other genes in offspring. This is not to say, on the other hand, that we should deliberately increase the amount of disease or gross genetic abnormality or inherited mental deficiency, for instance. There clearly would come a stage where a community could not afford (in economic or organisational terms) to have such numbers of diseased people on its hands that the options of the rest of society to fulfil their lives in diverse ways were cancelled. Each family, each local community, solves this problem reasonably by deciding how much of its resources it will devote to medical activity, and how much potential inherited disease it will avoid by marriage laws and contraception and early abortion and sterilisation and genetic manipulation and so on, but such decisions should always be left to the people immediately involved, so that here too the principle of diversity can operate, for some will decide one way, some another, influenced more or less by general social approval.

But, you may say, if we know about this sort of thing, can we not plan to circumvent it? Are we not finally directed by our brains, not by our bodies? Can we not control the environment, make it uniform, and then have everyone genetically suited to it in a bodily way so that none will be diseased? Then for variety they could think different thoughts, which would give us the flexibility for future unexpected events.

Let us look at the proposal. It takes us straight into science fiction. But let us look at it.

First, can we hope to control the environment and make it uniform to that extent? It would mean the same temperature range and climatic conditions, the same food, the same population density everywhere, the same people. Probably it could be done, eventually. But how can you get people to think different thoughts if they have the same cultural patterns, for that is what they would have to have. And if people are truly the same they would all have to be the same sex, and anyway vegetative rather than sexual reproduction would be the only certain way of keeping the stock uniform, so we would probably have to settle just for the female and eliminate the male. Then, without sex drives, without family tensions, without rivalry, would we have much spur to original thinking? Identical twins, even separated ones, think very similar thoughts. It is likely to be the same if we achieve genetic uniformity. But suppose we did achieve this uniform controlled environment and uniform genetically stabilised man. And then suppose the environment changed just a little, in spite of us, say a mutation in a virus or bacterium we had not reckoned with, say a little more or less solar activity, say another quick ice age, and—poof!—we might all be gone, because our intellects and our culture might very well have failed to elaborate all the possible patterns of contrived response. We might even have chosen a strain of ourselves that was biochemically incapable of conceiving by intellectual means a mental model of the disaster that was approaching to destroy us.

I think in fact all the evidence is that the controlling power of the self-conscious intellect over the cellular and other unconscious reactions of the body inside and outside the central nervous system is extremely weak and marginal and not to be relied on alone.

The conscious intellect supplements the genetic information in the individual. It has the great advantage that it gets survival information not only from forebears, as does the genetic system, but across the generations, and through written and other symbols even over great gaps in time and distance. The conscious intellect is largely an organ of social action and interaction, and is responsible for the technological processes by which we are rapidly 'exploiting' the environment of our planet. In fact, at the moment it is allowing us to 'exploit' at such an exponential rate that many of the unique diversities in that environment are disappearing. Nations are coalescing, and human populations are increasing so fast that soon we shall have reduced our various homelands to their Lowest Common Environments, something quite uniform, and from the point of view of encouraging physical diversity, dangerously like what I described a few minutes ago.

The evolutionary process has, as you would expect, conditioned our minds so that we want to survive. It happens also that we know that we want to survive, and so on. This can be disturbing, especially where it leads to perverse activity that is against the already built-in survival strategies of the enzymes and cells.

For instance, suppose, egged on by our intellects, we breed so many people that we have no environmental diversity left, even if we stop short of breeding so many that we run out of nitrogen or something like that. This would be against the strategy of our biological natures. Therefore we must control population size.

You notice that starting with the proposition that all men are molecularly different and by finding that for us to survive they must remain so, we are beginning to derive precepts for living. It would not be surprising if these turned out to be rather old hat and very like some of the rules of the established traditional religions, for the social policies enjoined by such religions have been tested in the environment too, and must have given way in the past where they happened to be inconsistent with the inescapable molecular biology of man. So they have been selected to some extent already, though not yet in a modern technological environment.

An interesting point which I have already mentioned, but will mention again now, is that the molecules and the genes that underlie the New Biology are verifiable in laboratories throughout the world so that Intellectual Man may well eventually come to view Biological Man everywhere from the same scientific basis. This will be a world-view, without tendency to sectarianism, which is a great disability of unverifiable and unknowable God-systems.

Having begun to talk in religious terms, and having said that the

New Biology enables one to derive behaviour patterns for living, it would be unfair if I failed to derive a few, though I have no time to do this derivation in detail. They would go something like this:

Rely on verifiable biological truths about Man and his nature and put these into the very base of your educational system.

Conserve variety in local biological environments. Therefore do not overpopulate. After this, be diverse in bodies and minds. So breed sexually. Maintain the family. Marry the stranger. Look after your sick. Don't kill people. Tolerate the eccentric. Don't censor. Encourage private choice. Don't be vengeful. Don't have notions of absolute Right and Wrong for individuals. Keep communities small, so that they can be diverse too. So be parochial, or at least provincial. And be curious. Seek change. Take care.

Some of these precepts have been part of our traditional life for thousands of years. Many are neglected today. They may seem trite; like the remark that people are different, but only because, like it, they have a general quality. If we are to live in accord with the limitations of our natures, they should be heeded by every person, especially those in science, government, commerce, and administration. When every scientist, politician, and tycoon knows his biology many things will be ordered differently and our species will be safe for the time being.

If, perversely, they and we do not learn it, I think our species will still survive, but uncomfortably, for unless we do learn it and act on the knowledge we are likely to be in a state of serious and unnecessary maladaptation to our environment for a long dark age.

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4

Human Nature and Culture

DEREK FREEMAN

WILHELM Dilthey, the German neo-Kantian philosopher, has left us an account of how, on a night in 1894, there came to him an unnervingly ominous dream. He was staying at a castle in Silesia, and, after a long and soul-stirring philosophical discussion, had retired to his bedroom, where there hung a copy of Raphael's famous fresco 'The School of Athens'. As Dilthey slept, Raphael's painting came alive as philosophers of post-Renaissance times trooped in to join the ancients and the medievals; whereupon, the whole throng began to separate as though into opposing factions. To one side, around Archimedes and Ptolemy, the naturalistic thinkers gathered; on the other, the idealist philosophers around Socrates and Plato, with bands of mediators forming and re-forming in between. Then, as if impelled by some imperious force, all mediation having failed, the groupings began to recede one from the other, and great fissures opened in the ground between them as they were enveloped in hostile alienation.[1] At this awesome sight, Dilthey was overcome with anxiety; he felt, he tells us, as though the unity of his being was being torn asunder.

I have recounted this dread dream of Dilthey's because it prophetically epitomises what was indeed to happen to the sciences of man during the immediately ensuing decades, and points to consequences from which these sciences still suffer—some of them to the very marrow of their methodologies.

Charles Darwin, when he came to the end of his essay of 1859,

[1] W. Kluback, *Wilhelm Dilthey's Philosophy of History* (New York, Columbia University Press, 1956), pp. 103 ff; H. A. Hodges, *The Philosophy of Wilhelm Dilthey* (London, Routledge and Kegan Paul, 1952), pp. 312 ff.

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The Origin of Species by Means of Natural Selection, appended the laconic words: 'much light will be thrown on the origin of man and his history'.[2] With this aside—surely among the most pregnant in the brief history of science—was opened up the prospect that at least some members of 'Adam's sovereign clone' might transcend the banalities of their creation myth, and by dint of scientific inquiry, eventually come to a more truthful realisation of the realities of their phylogenetic past and of the springs of their evolving human nature.

In recent years, evolutionary theory has emerged saliently as the unifying paradigm of all the biological sciences, from biochemistry to ecology,[3] and its status has been radically enhanced by the advances of the last two decades in molecular biology, which as Muller put it, rank 'among the most magnificent and thrilling of all scientific revolutions that mankind has achieved thus far'.[4] So, with the discovery of the way in which genetic information can be stored on nucleic acid, the molecular basis of the evolutionary process has been revealed, and it has become apparent that 'the great specificity and subtlety shown by any particular enzyme'[5] is as much the result of natural selection as the clinging behaviour of a new-born langur monkey or the capacity of an infant *Homo sapiens* to learn one of the modes of symbolic communication characteristic of his species.[6] Indeed, no informed biologist can now have grounds for disagreement with Muller's generalisation that 'the criterion for any material's having life is whether or not it has the potentiality . . . of evolution by Darwinian natural selection'.[7]

[2] C. Darwin, *The Origin of Species by Means of Natural Selection* (London, John Murray, 1859), p. 488.

[3] E. Mayr, *Animal Species and Evolution* (Cambridge, Mass., Harvard University Press, 1963), p. 1.

[4] H. J. Muller, 'Means and aims of human genetic betterment', in *The Control of Human Heredity and Evolution*, ed. T. M. Sonneborn (New York, Macmillan, 1965), p. 101.

[5] F. Crick, *Of Molecules and Men* (Seattle and London, University of Washington Press, 1966), p. 52.

[6] P. Jay, 'Mother-infant relations in langurs', in *Maternal Behaviour in Mammals*, ed. H. Rheingold (New York, John Wiley, 1963), p. 286; E. H. Lenneberg, *Biological Foundations of Language* (New York, John Wiley, 1967), p. 28 and pp. 128 ff.

[7] Muller, 'The gene material as the initiator and the organizing basis of life', in *Heritage from Mendel*, ed. R. A. Brink (Madison, University of Wisconsin Press, 1967), p. 443.

Evolutionary theory, then, provides a unifying paradigm for all the biological sciences—but it was not always so, and, if we are to grasp the significance of the new biology for the understanding of man and his behaviour, we must—paradoxically—return to the nineteenth century and relate the symbolism of Dilthey's dream to the vicissitudes of Darwin's theory.

The intellectual commotion that followed the publication of the *Origin of Species* is well enough known.[8] A comparable furore was created by the appearance, in 1871, of *The Descent of Man*.[9] As Tylor noted, during that same year, to many there seemed 'something presumptuous and repulsive' in the view that the history of mankind was 'part and parcel of the history of nature',[10] and so, during the last decades of the nineteenth century, there arose a number of related ideologies opposed to the notion of a naturalistic and evolutionary science of man. Moreover, not a few of those involved were themselves men of science. For example, it was Rudolf Virchow, celebrated for his contributions to cellular pathology, who at Munich in 1877 vehemently attacked Haeckel's 'monistic view of the origin and nature of man'.[11] Indeed, so deeply felt was Virchow's opposition that he gave voice to fears that 'the theory of descent' might bring to Germany the horrors of the Paris Commune, and then proceeded, on the basis of his own researches in 'the domain of prehistoric anthropology', vigorously to contest the theory that man was phylogenetically 'allied to the rest of the animal world'.[12]

While Virchow was thus combating 'the incubus called Descent',[13] a young man named Franz Boas, who was to become the founder and father of cultural anthropology in America, had already

[8] G. de Beer, *Charles Darwin: Evolution by Natural Selection* (London, Nelson, 1963), chapter 8.
[9] F. Darwin (ed.), *The Life and Letters of Charles Darwin* (London, John Murray, 1888), Vol. III, p. 133.
[10] E. B. Tylor, *Primitive Culture* (London, John Murray, 1871), p. 2.
[11] E. Haeckel, 'Charles Darwin as an anthropologist', in *Darwin and Modern Science*, ed. A. C. Seward (Cambridge, University Press, 1909), p. 145; cf. also *Nature* (1877), **16**: 491.
[12] R. Virchow, 'The liberty of science in the modern state', *Nature* (1877), **17**: 74 and 112.
[13] This was the phrase of Adolf Bastian, friend and collaborator of Rudolf Virchow, who was also an inveterate opponent of evolutionary theory; cf. Haeckel, *Freedom in Science and Teaching* (London, Kegan Paul, 1879), p. 7.

begun his studies in the physical sciences at Kiel. A few years later, in Berlin, the young Dr Boas came profoundly under the influence both of Virchow (with whom he came to share a life-long antipathy to evolutionary biology), and of neo-Kantian idealism, which led him to abandon the mechanistic *Weltanschauung* of the natural sciences.[14] In 1885 he was to take these beliefs with him to America, and, in 1894—the year of Dilthey's dream—in an address to the American Association for the Advancement of Science,[15] Boas propounded the doctrine of cultural determinism, which as it became adopted by his students, was to culminate in the alienation of cultural anthropology from the biological sciences in general, and from evolutionary biology in particular.

And that same year, in Europe, Emile Durkheim (an exact contemporary of Boas) was preparing for publication his treatise *Les règles de la méthode sociologique* which propounded the doctrine that 'social facts' were entirely unrelated to biological facts,[16] and so opened up a methodological chasm between sociology and the biological study of human societies.

So it was, with the doctrines of Boas and Durkheim as the catalysts of fission, that the social sciences began to recede from the biological and natural sciences. Dilthey's dream was being methodically acted out, and the stage was being set for the sterile nature-nurture controversies of the 1920s—of which we are all the intellectual heirs.

The most eminent of Boas's early students was Alfred Kroeber, who likewise evinced a keen antipathy to evolutionary theory, and was apt, at this period, to refer to those 'infected with biological methods of thought'.[17] Characteristically, it was Kroeber, in a series of papers beginning in 1915, who pursued to its methodological extreme the doctrine of cultural determinism he had acquired from Boas, arguing, with emphatic rhetoric, that there was an

[14] C. Kluckhohn and O. Prufer, 'Influences during the formative years', in *The Anthropology of Franz Boas*, ed. W. Goldschmidt (American Anthropological Association, Memoir No. 89, 1959), pp. 9 ff; P. Radin, 'The mind of primitive man', *New Republic* (1939), **98**: 303; G. Stocking, *Race, Culture and Evolution* (New York, Free Press, 1968), p. 138.

[15] F. Boas, 'Human faculty as determined by race', *Proceedings, American Association for the Advancement of Science* (1894), **43**: 218.

[16] E. Durkheim, *Les règles de la méthode sociologique* (Paris, 1895).

[17] A. L. Kroeber, 'Inheritance by magic', *American Anthropologist* (1916), **18**: 34.

'eternal chasm' between the cultural and biological. There was, proclaimed Kroeber (and his language could not have been more sweeping), an 'utter divergence between social and organic forces'; culture was 'an entity in itself', and entirely unconnected with the biological order and evolutionary process.[18] With this doctrine went a series of rudimentary assumptions which soon became fundamental to anthropological orthodoxy: human nature was (as Margaret Mead was subsequently to put it) 'the rawest, most undifferentiated of raw material';[19] there was, it was held, a 'generic unity' or 'equivalence of hereditary endowment' throughout the entire human species;[20] and from these two assumptions a third was derived, the conclusion that 'every human expression' was completely moulded by 'social conditioning'.[21] Biological variables, by arbitrary pronouncement, had been completely excluded.

These implacable departures in cultural anthropology were paralleled by a militant movement in psychology, begun in about 1913 by John B. Watson, which came to be known as Behaviourism.[22] Initially, Watson was concerned primarily with breaking free from introspectionism, and he wrote bravely of his vision of psychology as 'a purely objective experimental branch of natural science'.[23] In the early 1920s, however, with Watson's resignation from Johns Hopkins University to become (in 1924) an advertising executive,[24] and under the influence of the anti-instinct movement in American social psychology,[25] Behaviourism became transformed into a rhetorical crusade against the recognition of biologically determined variables in human behaviour, and, within a few years, Watson was declaiming to the world that there was 'no such thing

[18] Kroeber, 'Eighteen professions', *American Anthropologist* (1915), **17**: 283–8; 'The superorganic', ibid. (1917), **19**: 163–213.
[19] M. Mead, 'Growing up in New Guinea' (1930), in *From the South Seas* (New York, Morrow, 1939), p. 212.
[20] Boas, *The Mind of Primitive Man* (New York, Macmillan, 1911), p. 155; L. Spier, 'Franz Boas and some of his views', *Acta Americana* (1943), **1**: 108.
[21] Spier, 'Some central elements in the legacy', in *The Anthropology of Franz Boas*, p. 146.
[22] J. C. Burnham, 'On the origins of behaviorism', *Journal of the History of the Behavioral Sciences* (1968), **4**: 143–51.
[23] J. B. Watson, 'Psychology as the behaviorist views it', *Psychological Review* (1913), **20**: 158.
[24] Watson in *A History of Psychology in Autobiography*, ed. C. Murchison (Worcester, Mass., Clark University Press, 1936), Vol. 3, pp. 279 ff.
[25] G. Adams, 'Human Instincts', *American Mercury* (1928), **14**: 458.

as any inheritance of capacity, talent, temperament, mental constitution and characteristics', and that 'nurture not nature' was responsible for what a child became in life.[26]

The distinction between nature and nurture is a hoary one; Prospero, it will be recollected, described the abhored Caliban as 'a devil, a born devil, on whose nature, nurture can never stick. . . '.[27] In the 1870s these terms were brought into scientific discourse by Galton in his pioneer researches on the life histories of identical twins.[28] However, at least since the time of Johannsen's fundamental distinction (of 1909) between genotype and phenotype,[29] no informed biologist has opposed heredity to environment as though the one might be wholly dominant over the other. Indeed, as Zirkle has pointed out, 'any attempt to make one more important than the other is as silly as trying to determine which is the more important in deriving a product, the multiplicand or the multiplier'.[30] In other words, on the nature-nurture issue biologists have long taken an interactionist position. As Dobzhansky has recently phrased it: 'The genotype and the environment are equally important, because both are indispensable. There is no organism without genes, and any genotype can only act in some environment.'[31] So, in 1915, while Kroeber was professing that 'heredity cannot be allowed to have acted any part in history',[32] we find the biologist Conklin (in the first edition of his book *Heredity and Environment in the Development of Man*) declaring that 'neither environment nor heredity is all-important . . . both are necessary to development'.[33]

At this distance in time it is a matter for wonderment that Kroeber, Watson, and the other fervent environmentalists of the 1920s should have had the intellectual temerity to take the extreme

[26] Watson, *Behaviorism* (New York, Norton and Co., 1925), p. 74; 'What is behaviorism?' *Harper's Magazine* (1926), **152**: 729.
[27] Shakespeare, *The Tempest*, Act IV, Scene I.
[28] F. Galton, 'The history of twins as a criterion of the relative powers of nature and nurture', *Journal of the Anthropological Institute* (1875), **5**: 391–406.
[29] W. Johannsen, *Elemente der exakten Erblichkeit* (Jena, Fischer, 1909).
[30] C. Zirkle, *Evolution, Marxian Biology and the Social Scene* (Philadelphia, University of Pennsylvania Press, 1959), p. 447.
[31] T. Dobzhansky, *Heredity and the Nature of Man* (New York, Harcourt, Brace and World, 1964), p. 55.
[32] Kroeber, 'Eighteen professions', *American Anthropologist* (1915), **17**: 285,
[33] E. G. Conklin, *Heredity and Environment in the Development of Man*, rev. ed. (Princeton, University Press, 1930), p. 72. (First edition was in February 1915.)

stance that they did. Their behaviour becomes understandable, however, when it is realised that biology, during the first quarter of this century, was itself in a state of profound confusion.

In 1880, in celebrating the 'coming of age' of *The Origin of Species*, in a lecture at the Royal Institution, T. H. Huxley felt justified in declaring that Evolution had taken its place 'alongside of those accepted truths which must be taken into account by philosophers of all schools'.[34] Within a few years of Darwin's death in 1882, however, the situation had begun to change. First came Weismann's trenchant critique of the doctrine of the inheritance of acquired characters,[35] a doctrine which Darwin himself had incorporated into evolutionary theory in the shape of his sterile Pangenesis hypothesis of 1868.[36] From the 1890s onward, other biologists began to express discontent with the principle of natural selection. With the unearthing, in 1900, of Mendel's results, a vain quarrel began between the mutationists and biometricians,[37] with the mutationists expressing ever-increasing doubts as to the efficacy of natural selection, until, in April 1914, we find Karl Pearson lamenting that the work of Darwin was being 'largely undermined'.[38] Later that same year—in Australia—in his Presidential Address to the British Association,[39] William Bateson conclusively rejected

[34] T. H. Huxley, 'The coming of age of the *Origin of Species*', *Nature* (1880), **22**: 4.

[35] Weismann's criticism of the doctrine of acquired characters was initiated by his remarks on heredity and the 'continuity of the germ-plasm' at a meeting held on 21 June 1883, when he was tendered the position of Vice-Rector of the University of Freiburg; cf. L. Cuénot, 'The inheritance of acquired characters', *Annual Report, Smithsonian Institution* (for the year ending 30 June 1921) (Washington, Government Printing Office, 1922), p. 336; cf. also A. Weismann, *The Germ-plasm: a Theory of Heredity* (London, Walter Scott, 1893).

[36] C. Darwin, *Variation of Animals and Plants under Domestication* (London, John Murray, 1868), Vol. 2, chapter XXVII.

[37] R. C. Punnett, 'The early days of genetics', *Heredity* (1950), **4**: 1–10; G. S. Carter, *A Hundred Years of Evolution* (London, Sidgwick and Jackson), p. 121; Mayr, 'Where are we?', *Cold Spring Harbor Symposia on Quantative Biology* (1959), **24**: 1 ff.

[38] K. Pearson, *The Life, Letters and Labours of Francis Galton* (Cambridge, University Press, 1914), Vol. 1, p. vi: in preface dated Galton Laboratory, 8 April 1914.

[39] As President of the Eighty-Fourth Meeting of the British Association for the Advancement of Science, William Bateson delivered two addresses, the first in Melbourne on 14 August and the second in Sydney on 20 August 1914; cf. *Report of the Eighty-Fourth Meeting of the British Association for the Advancement of Science, Australia, 1914* (London, John Murray, 1915), pp. 3–38.

Darwinian theory, and, falling back on preformist notions, advanced the view that all cases of genetic variation might be due to the loss of elements present in an original complex. Bateson's views were widely publicised,[40] and were greeted sympathetically by the leading American geneticist, T. H. Morgan, who, at that time, also held a mutationist theory of evolution.[41] Soon after this, Jennings was telling the Washington Academy of Sciences that 'the evolutionists might almost feel that the enemy had crept into their citadel and was blowing it up from within';[42] and, by 1922, in the course of a British Association symposium on Darwinism, as part of a chorus of criticism by Willis[43] and other eminent biologists, J. T. Cunningham was giving it as his opinion that natural selection was 'as extinct as the dodo'.[44]

[40] William Bateson's presidential addresses were also published in *Nature* (**93**: 635–42, 674–81), *Science* (**40**: 287–302, 319–33), and in the *Annual Report* (for 1915) of the Smithsonian Institution (Washington, Government Printing Office, 1916), pp. 359–94.

[41] T. H. Morgan, *A Critique of the Theory of Evolution* (Princeton, Princeton University Press, 1916); cf. also E. C. Jeffrey, 'Drosophila and the mutation hypothesis', *Science* (1925), **62**: 3–5.

[42] H. S. Jennings, 'Observed changes in hereditary characters in relation to evolution', *Journal of the Washington Academy of Sciences* (1917), **7**: 283.

[43] J. C. Willis, 'The inadequacy of the theory of natural selection as an explanation of the facts of geographical distribution and evolution', *Report of the Ninetieth Meeting of the British Association for the Advancement of Science, Hull, 1922* (London, John Murray, 1923), p. 399; cf. also Willis, *Age and Area* (Cambridge, University Press, 1922).

[44] Cf. *Nature* (1922), **110**: 752; J. T. Cunningham was one of the participants in a symposium on 'The Present Position of Darwinism', held jointly by the botanical and zoological sections during the course of the Ninetieth Meeting of the British Association for the Advancement of Science at Hull in September 1922. In his presidential address to Section K (Botany) at the Eighty-Ninth Meeting of the British Association in Edinburgh on 9 September 1921, Professor D. H. Scott, F.R.S., had given it as his opinion that 'for the moment, at all events, the Darwinian period is past' (cf. *Nature* (1921), **108**: 154); and later that year in Toronto, on 28 December 1921, William Bateson, in an address to the American Association for the Advancement of Science, renewed his criticism of the Darwinian theory of evolution by natural selection (cf. *Science* (1922), **55**: 55–61). Bateson's views were given great notice in the popular press (cf. H. F. Osborn, 'William Bateson on Darwinism', *Science* (1922), **55**: 194–7), and were used by those who in the immediately following years attempted to suppress the teaching of evolutionary theory in certain of the southern and western states of the U.S.A. (cf. W. Bateson, 'The revolt against the teaching of evolution in the United States', *Nature* (1923), **112**: 313–14; including Bateson's statement that it was he who, 'all unwittingly dropped the spark which started the fire').

By this time Fisher and Haldane[45] had already begun the mathematical researches, which, with those of Sewall Wright and others,[46] were to reconcile the facts of genetics with the process of natural selection, and to result in the rise of the synthetic theory of evolution—that 'mutated phoenix' (as Julian Huxley has called it)[47]—which now reigns supreme in modern biology. But this new epoch did not effectively begin until about 1930, with the publication of Fisher's classic essay *The Genetical Theory of Natural Selection*, and, during most of the second and third decades of this century, evolutionary biology was beset by discord and confusion.[48]

So it was that during this period, Kroeber, Watson, and others were able to promulgate their extreme environmentalist views. Behaviourism, it is instructive to note, was based on 'tacit assumptions' almost identical with those of cultural anthropology, these assumptions being, as the Brelands have stated them, that 'the animal comes to the laboratory as a virtual *tabula rasa*, that species differences are insignificant, and that all responses are about equally conditionable to all stimuli'.[49] Here also, it will be observed, phylogenetically-given variables are arbitrarily excluded.

Whatever may have been the scientific inadequacies of Behaviourism, its appeal was immense. Watson's book of popular lectures, when it was first published in 1925, was declared in the *New York Herald-Tribune* to be perhaps the 'most important book ever written',[50] and his doctrines soon became the gospel of the late 1920s. By 1927, V. F. Calverton, in the *Modern Quarterly*,[51] was

[45] R. A. Fisher, 'The correlations between relatives on the supposition of Mendelian inheritance', *Transactions, Royal Society of Edinburgh* (1918), **52**: 399–433; cf. also J. B. S. Haldane's papers on 'A mathematical theory of natural and artificial selection', which were published in the *Proceedings of the Cambridge Philosophical Society* from 1924 onwards, and which were summarised in Haldane's *The Causes of Evolution* (London, Longmans Green, 1932), pp. 171–215.

[46] S. Wright, 'Evolution in Mendelian populations', *Genetics* (1931), **16**: 97–159; cf. also Wright, *Evolution and the Genetics of Populations*, Vol. 1, Genetic and biometric foundations (Chicago and London, University of Chicago Press, 1968); A. H. Sturtevant, *A History of Genetics* (New York, Harper and Row, 1965), chapter 17.

[47] Julian Huxley, *Evolution: the Modern Synthesis* (London, George Allen and Unwin, 1942), p. 28.

[48] de Beer, *Charles Darwin: Evolution by Natural Selection*, p. 183.

[49] K. and M. Breland, 'The misbehavior of organisms', in *Readings in Animal Behavior*, ed. T. E. McGill (New York, Holt, Rinehart and Winston, 1965), p. 459.

[50] Cf. *Nation*, 13 January 1926.

referring to environmentalism as the 'great movement' underlying contemporary thought, and there was talk of 'a new enlightenment'.[52] The analysis of this fascinating epoch in intellectual history I must leave to another occasion. For the present, I only wish to note that the paradigm in terms of which many of the social sciences still operate was largely derived from the doctrines and assumptions of the uncompromising environmentalism of the 1920s and 1930s. Moreover, it is in the murky light of this paradigm that many educated people still think about human nature and culture. What bearing, then, have the advances of the last few decades in the biological sciences had on the doctrines and assumptions of such men as Kroeber and Watson, and on the related paradigm of certain of the social sciences?

Let me begin with an examination of the assumption that in all human populations there is an 'equivalence of hereditary endowment'. This assumption, often also referred to as the principle of the psychic unity of mankind,[53] is akin to the widespread notion that there is a unitary and uniform nature which we all share, and which, one of these days when we have sufficient knowledge, it will be possible to typify. We are here confronted with an example of typological thinking of a kind that is quite incompatible with the findings of modern population genetics. In Ernst Mayr's judgment, 'the replacement of typological thinking by population thinking is perhaps the greatest conceptual revolution that has taken place in biology';[54] without question, it is an innovation in understanding that is fundamental to the new biology.

With the recognition of the fact that the genetic processes involved in evolution operate in populations, there has, in recent decades, been much research in this field, and one of the notable outcomes has been the demonstration that natural populations of outbreeding diploid species, including man, far from being genetically uniform, are genetically highly heterogeneous.[55] Furthermore,

[51] V. F. Calverton, 'The analysis of behavior', *Modern Quarterly* (1927), 4: 302.

[52] S. D. Schmalhausen, *Why We Misbehave* (New York, Macauley, 1928), p. 17.

[53] M. Harris, *The Rise of Anthropological Theory* (London, Routledge and Kegan Paul, 1968), p. 15.

[54] Mayr, *Animal Species and Evolution*, p. 5.

[55] J. M. Thoday, 'Selection and genetic heterogeneity', in *Genetic Diversity and Human Behavior*, ed. J. N. Spuhler (Chicago, Aldine Publishing Co., 1967), pp. 89–98.

this genetic diversity is seen as adaptive, for in many vertebrate species it is an array of genotypes which enables a Mendelian population both to maintain its hold on any particular ecological niche, and to react adaptively to environmental change. This diverse array of genotypes within an outbreeding population is due to the independent behaviour of chromosome pairs during meiosis. Thus man, with 23 chromosome pairs, produces gametes (or germ cells) with any of the two to the power twenty-three alternative genomes (or haploid chromosome sets). This, as Hirsch has pointed out, makes 'vanishingly small' the chance that any two children of a given sexual union (with the exception, of course, of monozygotic twins) will be genetically identical, the probability (as Hirsch has calculated it) being less than 1 in over 70 trillion.[56] The probability that two unrelated individuals will have the same genotype is effectively nil. In other words, all human beings (with the exception, again, of monozygotes), from the time of their conception, possess a genotype or biological endowment of a *uniquely individual kind*. It follows, as Dobzhansky has phrased it, that 'the nature of man as a species resolves itself into a great multitude of human natures', and that human nature is 'not unitary but multiform'.[57]

This is not, of course, to deny that there are behavioural mechanisms specific to all members of the human species; what it does mean is that due regard must be paid to individual variability in any comparative study of these mechanisms. Further, there are now sound scientific grounds for the full recognition of individuality in

[56] J. Hirsch, 'Behavior genetics and individuality understood', *Science* (1963), **142**: 1437. It should be noted that the trillion is here the American one (10^{12}). As Professor D. G. Catcheside, F.R.S. (Director, Research School of Biological Sciences, Australian National University) has kindly pointed out to me, the situation is, in fact, not so simple as '2^{23} alternative genomes', where the assumption is made that each of these is different, which is further dependent on the assumption that the two members of each chromosome pair are different. Professor Catcheside comments: 'While this is probable in man and other outbreeding organisms, it is not necessarily true. However, the diversity is likely to be increased by virtue of any pairs of chromosomes within which there are two or more genetic differences which may be reassorted by crossing over. Thus the possible number of gametes is decreased by a factor of two for every chromosome pair which has no genetic difference between its members and increased by a factor of two for each genetic difference in excess of one in each chromosome pair with two or more differences'.

[57] Dobzhansky, *Heredity and the Nature of Man*, p. 49; 'Of flies and man', *American Psychologist* (1967), **22**: 42.

the analysis of social and cultural behaviour; the way in which one individual plays a role (however it be ritualised) will be different from the way the next individual plays it, and this difference, the evidence indicates, will, to a significant degree, be genetically determined.

It also follows from the discoveries of population genetics that a human being, when he issues from his mother's womb, is not, in behavioural terms, a *tabula rasa*, and the 'most undifferentiated of raw material', for, as we have seen, human beings are intrinsically variable before they undergo differentiating experiences'.[58] This conclusion, moreover, has been borne out in recent years by researches carried out at the Neonatal Behavioural Laboratory at the Albert Einstein College of Medicine, which have demonstrated 'consistent individual differences in response intensity' in human neonates 'during the first few days of life'.[59]

The notion, so prevalent among psychologists and anthropologists in the 1920s and 1930s, that the human neonate was a mere 'reaction-machine',[60] was accompanied, as might be expected, by a total rejection of evolutionary theory, or 'the mentalistic continuity doctrine', as a prominent psychologist of the time scathingly called it.[61] Thus, the view that man's behavioural repertoire might, in significant ways, be phylogenetically determined was completely rejected, and it was held, as the social psychologist Kantor stated it in 1924, that for the human species, behaviour began and ended with 'the individual's actual interactions with his stimuli conditions'.[62]

This simple-minded, stimulus-response, chain-reflex model of behaviour was essentially a speculative construct owing nothing to the findings of comparative neurophysiology as they then existed, for it was at this very time that the meticulous experimental research

[58] Hirsch, 'Behavior genetics and individuality understood', p. 1437.

[59] W. H. Bridger and B. Birns, 'Experience and temperament in human neonates', in *Early Experience and Behaviour: the psychobiology of development*, ed. G. Newton and S. Levine (Springfield, Illinois, Charles C. Thomas, 1968), p. 89; cf. also H. Papousek, 'Genetics and child development', in *Genetic Diversity and Human Behavior*, pp. 171–86.

[60] V. F. Calverton, 'The rise of objective psychology', *Psychological Review* (1924), **31**: 426.

[61] J. R. Kantor, 'An attempt toward a naturalistic description of emotions', *Psychological Review* (1921), **28**: 131.

[62] Kantor, *Principles of Psychology* (New York, Knopf, 1924), p. 172.

of men like Coghill and Lashley[63] was demonstrating conclusively the scientific inadequacy of an empty-organism, peripheralist paradigm. Soon after this, von Holst disproved the chain-reflex hypothesis[64] by demonstrating, for example, that a completely deafferented spinal eel can still swim in a well co-ordinated manner. And this was followed by the brilliantly executed researches of Weiss and many others[65] in which the neuro-muscular connections in various vertebrates were surgically rearranged. In no instance could the animals operated on learn to overcome the anatomical disarrangement. These and other comparable experiments showed, in the words of Lenneberg, 'that motor co-ordination (and certain behaviour patterns dependent upon it) is driven by a rigid, unalterable cycle of neuro-physiological events inherent in a species' central nervous system'.[66] This conclusion that certain of the basic behaviour mechanisms of a species are phylogenetically programmed in the central nervous and related systems was further demonstrated, from the 1950s onwards, by the researches of such notable investigators as von Holst, MacLean, Delgado, Penfield, and Heath,[67] in which the brains of a variety of vertebrate species, including man, were explored by the method of direct electrical stimulation by means of implanted micro-electrodes.

[63] G. E. Coghill, *Anatomy and the Problem of Behavior* (New York, Macmillan, 1929); K. E. Lashley, 'The relation between cerebral mass, learning and retention', *Journal of Comparative Neurology* (1926), **41**: 1–58.

[64] E. von Holst, 'Uber den Prozess der zentralnervösen Koordination', *Pflügers Arch. ges. Physiol.* (1935), **236**: 149–58; cf. K. Lorenz, 'Morphology and behavior patterns in closely allied species', in *Group Processes, Transactions of the First Conference*, ed. B. Schaffner (New York, Josiah Macy Jr Foundation, 1955), p. 183: 'I think we can now accept it as a fact that the central nervous system can generate and co-ordinate nervous impulses without any afferent inflow'.

[65] P. A. Weiss, 'Experimental analysis of co-ordination by the disarrangement of central-peripheral relations', *Physiological Mechanisms in Animal Behavior: Symposia of the Society for Experimental Biology* (New York, Academic Press, 1950), **4**: 92–111; cf. also R. W. Sperry, 'Physiological plasticity and brain circuit theory', in *Biological and Biochemical Bases of Behavior*, ed. H. F. Harlow and C. N. Woolsey (Madison, University of Wisconsin Press, 1958), pp. 401–24.

[66] Lenneberg, *Biological Foundations of Language*, p. 19.

[67] E. von Holst and U. von Saint Paul, 'On the functional organization of drives', *Animal Behaviour* (1963), **11**: 1–20; P. D. MacLean, 'New findings relevant to the evolution of psychosexual functions of the brain', *Journal of Nervous and Mental Disease* (1962), **135**: 289–301; J. M. R. Delgado, 'Cerebral heterostimulation in a monkey colony', *Science* (1963), **141**: 161–3; W. Penfield and T. Rasmussen, *The Cerebral Cortex of Man: a clinical*

Much of this work has been undertaken in close conjunction with research by ethologists—whose discoveries and theories are also very much a part of the new biology. The principal achievement of ethology has been the demonstration of the truth of Darwin's supposition (in his book *The Expression of the Emotions in Man and Animals*) that many behaviour mechanisms are phylogenetic adaptations; in other words, that such behaviour mechanisms have evolved in the same manner as other features of animal populations by process of natural selection, and so are transmitted, from generation to generation, in the genetic code. That this in fact occurs in infra-human animals can now, in the light of the findings of ethology and behaviour genetics, be taken as demonstrated.

Indeed, as the behaviour geneticist Aubrey Manning has described,[68] an animal may possess within its nervous system the equivalent of an encoded 'picture' of the normal environment, and the appropriate responses to make to it. Further, the results of a recent experiment by Sackett[69] indicate that comparable innate recognition mechanisms exist even among species of the zoological order to which we ourselves belong. In Sackett's experiment, solitary young rhesus monkeys, reared in isolation from birth, and deprived of any opportunity of observing their own reflections, were enabled, by pressing levers, to project coloured slides on the walls of their cubicles. These slides depicted a range of objects, including a number of monkeys. Sackett's experimental subjects showed a marked preference for pictures of conspecifics, and especially for those of infant rhesus monkeys. Further, an early preference for pictures of threatening older rhesus monkeys persisted until about 2½ months of age, when fear responses were displayed and such pictures were avoided. In view of the fact that these infant monkeys had not experienced any social communication with conspecifics (or any other animal species), their recognition of an expression of

study of localization of function (New York, Macmillan, 1952); R. G. Heath, 'Pleasure response of human subjects to direct stimulation of the brain: physiologic and psychodynamic considerations', in *The Role of Pleasure in Behavior*, ed. R. G. Heath (New York, Hoeber Medical Division, 1964), pp. 219–43.

[68] A. Manning, 'Drosophila and the evolution of behaviour', in *Viewpoints in Biology*, ed. J. D. Carthy and C. L. Duddington (London, Butterworths, 1965), **4**: 126.

[69] G. R. Sackett, 'Monkeys reared in isolation with pictures as visual input: evidence for an innate releasing mechanism', *Science* (1966), **154**: 1468–73; cf. also R. L. Fantz, 'The origin of form perception', *Scientific American* (1961), **204** (5): 66–72.

threat becomes strong evidence for the existence in the rhesus monkey of phylogenetically programmed receptor mechanisms which make such reception possible.

In infra-human animals, then, the neonate is no behavioural *tabula rasa*. But this fact will cause no surprise to the evolutionary biologist, who recognises how vital to survival certain behaviour mechanisms are; who understands that these behaviour mechanisms have emerged in the course of evolutionary history because they contributed decisively to the reproductive success of the animal populations in which they were found, and who, from his knowledge of molecular biology, is aware that the genetic code is capable of storing and transmitting a quantum of exceedingly intricate information. As Francis Crick has graphically put it, the DNA molecules from just one sperm cell carry sufficient information, if it were written out, to 'fill about five hundred large books, all different —a fair-sized private library'.[70] An embryo's genotype, then, is an evolved compilation of astonishingly intricate instructions, not only for the building of such a marvellously complex structure as the central nervous system, but also for its behavioural operation. Or, to put it in another way, a genotype is the conditioning with which a living organism enters its environment, fitted to utilise it, this conditioning being the cumulative product of genetic adaptation to a succession of ever-changing environments during countless past generations. And these are conclusions which indubitably apply to us all, for one of the facts of which we may all be sure is that all of our lineal ancestors—back to the Miocene and beyond—reached reproductive age.

What then of the human neonate? Like other primate neonates, we find him equipped with a range of fixed action patterns, such as reflexive rooting and sucking, as well as displaying spontaneous cyclic activity, which as Teitelbaum has remarked,[71] is 'instinctive rather than reflexive', being strongly influenced not merely by external stimuli but by internal states as well. Nonetheless, the manifest behavioural repertoire of a new-born human infant is conspicuously limited. It was this superficial impression, perhaps more than anything else, which led Watson to the facile and erron-

[70] Crick, *Of Molecules and Men*, p. 58.

[71] P. Teitelbaum, 'The biology of drive' in *The Neurosciences*, ed. G. C. Quarton, T. Melnechuk, and F. O. Schmitt (New York, Rockefeller University Press, 1967), p. 559.

eous conclusion that in the human species heredity counted for 'almost nothing', and led him to describe the human neonate as 'a piece of unformed protoplasm'.[72] What he failed to realise was that the genetic determination of the behaviour of an individual is far from over at birth. And here we come to the notable discoveries, in recent decades, of developmental biology. In the words of Frank Beach, 'the genotype is in continuous operation as far as its effects on behaviour are concerned';[73] and further, it is now known that genes are 'turned on and off' in the course of ontogeny in intimate interaction with the environment, so producing the phenomenon of the critical or sensitive period of behavioural development.

Perhaps the best known example of this is imprinting in certain species of birds, to which attention was first drawn by Konrad Lorenz in the 1930s.[74] Since then, critical periods for learning have been discovered in a wide range of social animals; among most breeds of dog, for example, as Scott and Fuller report, the optimum period for social bonding is between the sixth and eighth weeks.[75] Similarly, there is now a convincing body of evidence that there is a critical period for primary social bonding in the human species, beginning at a point in maturation reached at about three months or thereabouts, and marked by the onset of a persistent alpha rhythm of three to four waves per second in the electrical activity of the infant's brain.[76] This evidence, moreover, indicates (as does the comparative evidence from primatology)[77] that human kinship

[72] J. B. Watson, *Psychological Care of Infant and Child* (London, George Allen and Unwin, 1928), p. 18; Watson *et al.*, 'Is man a machine?' *Forum* (1929), **82**: 265.

[73] F. A. Beach, 'Ontogeny and living systems', in *Group Processes*, p. 14.

[74] K. Lorenz, 'Companionship in bird life' (1935), reprinted in *Instinctive Behavior*, ed. C. H. Schiller (London, Methuen, 1957), pp. 83–128.

[75] J. P. Scott and J. L. Fuller, *Genetics and the Social Behavior of the Dog* (Chicago and London, Chicago University Press, 1965), chapter 4.

[76] J. P. Scott, 'The process of primary socialization in canine and human infants', *Monograph of the Society for the Research into Child Development* (1963), **28**: 1–47; D. B. Lindsley in *Brain Function*, ed. C. D. Clemente and D. B. Lindsley (Berkeley and Los Angeles, University of California Press, 1963), **5**: 73 ff.

[77] M. Yamada, 'A study of the blood-relationship in the natural society of the Japanese macaque', *Primates* (1963), **4**: 43–65; A. Tsumori, 'Newly acquired behavior in social interactions of Japanese monkeys', *Social Communication among Primates*, ed. S. A. Altman (Chicago and London, University of Chicago Press, 1967), pp. 207–19; J. van Lawick-Goodall, 'The behaviour of free-living chimpanzees in the Gombe stream reserve', *Animal Behaviour Monographs* (1968), Vol. 1, Part 3, pp. 222 ff.

behaviour is phylogenetically based—a conclusion with profound implications for social anthropology and allied disciplines. There are also immediately practical implications; for example, J. P. Scott, a distinguished investigator of the process of primary socialisation, counsels those who would acquire a dog to do so, if possible, when it is between six and eight weeks of age; and he has recently advised that the adoption of a human infant should, ideally, occur 'as soon as possible after birth and no later than the first six months of life'.[78]

Another instance is the critical period for language acquisition in the human species, the evidence for which has recently been presented by Lenneberg in his book *Biological Foundations of Language*. With the human infant the development of language does not begin until the age of 18 months or thereabouts, at which stage highly complex verbal behaviour is acquired naturally—that is without formal instruction. We tend to take this extraordinary event, like so many biological phenomena, for granted; but we might well ask why the development of language behaviour does not take place earlier, as at 6 months when the infant is equally exposed to the verbal behaviour of those around him. The reason, the biological evidence suggests, is because the genetically monitored maturation of the nervous system has not yet reached the requisite sensitive period. When it does, however, the development of verbal behaviour is, as Hockett has expressed it,[79] 'as inevitable as menarche or the appearance of axillary hair, and genetically more stable than either'. In other words, as Lenneberg concludes, 'the *processes* by which the realized outer structure of a natural language comes about are deeply-rooted species-specific, innate properties of man's biological nature'.[80]

Rousseau in his enchanted dream was convinced that it might be possible to teach apes to converse like men. This, we now know, is 'against the use of nature', for a series of scientific investigations have shown that 'even amid human surroundings' a young chimpanzee 'never prattles and babbles' as a human infant does when beginning to talk,[81] this being for the good reason that the chim-

[78] Scott, 'The process of primary socialization in the dog', p. 435.

[79] C. F. Hockett, review of *Biological Foundations of Language* by E. H. Lenneberg, *Scientific American* (1967), **217** (5): 142.

[80] Lenneberg, *Biological Foundations of Language*, p. 394.

[81] W. N. Kellog, 'Communication and language in home-raised chimpanzees', *Science* (1968), **162**: 423–6.

panzee species has not evolved a genotype that permits the development of the brain mechanisms to sustain symbolic verbal behaviour. In such ways, then, whatever be the vaunting whims of men, 'nature her custom holds'.

In discussing the activation of genes during the course of ontogeny I noted that this occurs 'in intimate interaction with the environment'. Let me further emphasise that the recognition of the genetic determinants of behaviour in no wise involves neglect of the environmental determinants. Indeed, one of the major facets of the new biology is the meticulous experimental study of the both profound and subtle ways in which environmental forces influence the development of individual organisms, and particularly during the course of early experience. It is this which René Dubos has recently called 'Biological Freudianism',[82] and many examples of such research could be cited, from Thompson's experiments on the influence of prenatal maternal anxiety on emotionality in young rats, to Gottlieb's recent demonstration that duck embryos (that is, still in the egg) are influenced by duck noises occurring in the outside world, and that such stimulation is essential to the development of their species-specific auditory perception.[83]

We are here dealing with behavioural plasticity, which is generally characteristic of the most recently evolved vertebrate class, the mammals, and especially characteristic of the most recently evolved order of that class, the primates, above all, of that primate of primates, *Homo sapiens*. The existence of this behavioural plasticity does not, however, preclude the existence of genetic diversity in populations, or the existence of genetically programmed behaviour mechanisms in individual organisms. Viewed in evolutionary perspective, therefore, learning behaviour is a phylogenetic adaptation, a way of completing the differentiation of the central nervous and related systems 'in greater detail and more adaptively than can be accomplished by gene encoding alone',[84] and it is this evolutionary innovation which has made possible the adaptive radiation which we observe in the diverse cultures of man.

[82] R. J. Dubos, *So Human an Animal* (New York, Scribner, 1968), p. 77.
[83] W. R. Thompson, 'Influence of prenatal maternal anxiety on emotionality in young rats', *Science* (1957), **125**: 698–9; G. Gottlieb, 'Prenatal behavior in birds', *Quarterly Review of Biology* (1968), **43**: 148–74.
[84] J. L. Fuller and W. R. Thompson, *Behavior Genetics* (New York, John Wiley, 1960), p. 4.

A stage has now been reached, then, in the biological study of behaviour where any rigid and pervasive dichotomy between innate and acquired responses has become otiose. Galambos, in his recent discussion of the brain correlates of learning, has written: 'every sample of behaviour reveals an aspect of the past history of the organism that has been stored within the brain. These memories arise both via genes and through experience . . . '; and he has suggested that 'all of them come into existence, are stored, and receive their expression through fundamentally the same mechanisms'.[85]

Thus, the discoveries of recent decades demand of the student of animal and human behaviour *an interactionist paradigm* which gives recognition to genetical and environmental feedback and interaction both in the ontogeny of individual organisms and in the phylogeny of breeding populations.

This interactionist paradigm, it will be seen, is markedly at variance with that contrived by Kroeber, Watson, and the other intransigent environmentalists of the 1920s and 1930s, and its emergence has been the chief cause of the ferment that has been abroad in the behavioural sciences in recent years, and particularly since the advent of behaviour genetics in the early 1960s. Today, I would doubt if there are any informed behavioural scientists who would wish to take other than an interactionist position, and this must be ranked as one of the principal happenings in the scientific progress set in motion by the new biology.

Further, the interactionist paradigm has given rise to the exciting prospect of a unified science of man and his behaviour. For example, the recent major symposium on 'Biology and Behaviour', held at Rockefeller University, had as its aim, according to Carl Pfaffman, the initiation of 'a period from which a unitary science of man will emerge in which his biochemistry, biophysics and biology will be integrated with the understanding of his behaviour'.[86]

As a result of this progress, and the present scientific supremacy of the interactionist paradigm, not a few social scientists and others,

[85] R. Galambos, 'Brain correlates of learning', in *The Neurosciences*, p. 641.
[86] C. Pfaffman, Introduction to *Neurophysiology and Emotion* (first of a series on Biology and Behavior, proceedings of a conference held under the auspices of the Russell Sage Foundation and the Rockefeller University), ed. David C. Glass (New York, Rockefeller University Press and Russell Sage Foundation, 1967), p. ix.

trained in yesteryear, now find themselves far out on a conceptual limb not of their own making—and this can no longer be regarded as a salubrious intellectual situation in which to be. In other words such has been the progression in biological discovery and understanding during recent years that no one who professionally concerns himself with the study of men and their ways can afford any longer to pride himself on his illiteracy in matters biological. Rather, one would hope and expect that before long suitable courses on the evolutionary and biological bases of behaviour will become a recognised part of professional training in all disciplines in any way concerned with human behaviour.

In recent years there have also been major changes in our understanding of the probable nature of human evolution. As I noted earlier, the cultural anthropologists of the early decades of this century would have no truck with Darwin's theory of evolution by natural selection. Thus, Kroeber, having asserted that 'nothing homologous to the rudest culture' existed even among 'the highest animals', went on to advance the theory that culture had not evolved gradually in the course of human phylogenesis, but had originated by a sudden 'leap to another plane'.[87] The subsequent discoveries of prehistoric archaeology and of the ethological study of infra-human primate behaviour have reduced Kroeber's theory to the status of a private fantasy, for it is now known, from the researches of Dr Jane van Lawick-Goodall and others among wild chimpanzees in central Africa,[88] as also from those of Dr Kawai and his associates on the Japanese monkey,[89] that rudimentary cultural behaviour does indeed exist among infra-human primates; furthermore, both the palaeontological and archaeological evidence demonstrate an unbroken evolutionary continuity. Kroeber's theory, therefore, must be rejected, as also, on genetical grounds,

[87] Kroeber, 'The morals of uncivilized people', *American Anthropologist* (1910), **12**: 437; 'The superorganic', *American Anthropologist* (1917), **19**: 163–213; cf. p. 208: 'Social evolution is without antecedents in the beginnings of organic evolution . . . the dawn of the social thus is not a link in any chain, not a step in a path, but a leap to another plane'.

[88] Lawick-Goodall, 'The behaviour of free-living chimpanzees in the Gombe stream reserve', pp. 202 ff; A. Kortlandt and M. Kooij, 'Protohominid behaviour in primates', *Symposia of the Zoological Society of London* (1963), **10**: 61–88; Korlandt, 'On tool-use among primates', *Current Anthropology* (1966), **7**: 215–16.

[89] M. Kawai, 'Japanese monkeys and the origin of culture', *Animals* (1965), **5**: 450–5.

must the Lamarckian theory of human domestication advanced by Boas.[90] From a multitude of scientific discoveries, then, it has become plain that evolution by natural selection has gradually created the human species, as it has all other populations of living things—but with certain innovations which seem to have occurred mainly in the evolutionary history of the *Hominidae*—that is of *Homo sapiens*, and the fossil species related to him.

And here I would like to pay tribute to the work of Sherwood Washburn, the distinguished American evolutionary anthropologist, whose researches and interpretations (with those of his many collaborators and colleagues) are leading to the emergence of a new anthropology. Among the most important of Washburn's notions is the inference that the gene pools of hominid populations evolved in a feedback relationship with nascent cultural behaviour. Thus, in Washburn's words:

> The success of initial tool using, perhaps only slightly more advanced than that seen in the contemporary chimpanzee, led to selection for the biology that made tool using possible, and the study of the brain of *Homo sapiens* shows that large areas are associated with hand skills. The reason that tool making evolved so slowly was that the brain had to evolve before the skills of *Homo erectus* were anatomically possible. According to this view the explanation of human evolution is to be sought in the feedback relation between successful behaviour and the biology that makes the behaviour possible.[91]

In other words, a cultural innovation is an addition to the previously existing environment with consequent feedback or selective pressure on the breeding population and its gene pool; which means, it will be discerned, that instead of being 'utterly divergent', as Kroeber in his ignorance supposed, cultural behaviour and man's biological nature have, on repeated occasions in the unbroken course of evolution, been in communication at the molecular level, for, as J. B. S. Haldane has succinctly phrased it, 'the principal unit process in evolution is the substitution of one gene for another at the same locus'.[92]

[90] Boas, 'Human faculty as determined by race', pp. 309 ff; *The Mind of Primitive Man*, pp. 75 ff; 'The aims of anthropological research, *Science* (1932), **76**: 607.

[91] S. L. Washburn, 'Behavior and the origin of man', *Rockefeller University Review* (1968), January-February, p. 17.

[92] Haldane, 'The cost of natural selection', *Journal of Genetics* (1957), **55**: 511.

We may say then that the species *Homo sapiens* is pre-eminently the evolutionary product of the new selective pressures that came with the emergence of rudimentary forms of culture—this emergence going back some millions of years, at least into the Pliocene, and possibly, as Leakey has recently suggested,[93] into the Miocene. It follows that, in the study of human evolution, prehistoric archaeology and the comparative analysis of cultural behaviour become as important as genetics, the neurosciences, ethology, and ecology; and further, that the relevant concepts and findings of all these and various cognate sciences must be integrated if the aetiology of human evolution is to be fully comprehended.

With the advent of cultural behaviour, then, our hominid ancestors entered a new phase of evolutionary development in which behavioural adaptations dependent on the transfer of information from generation to generation by other than wholly genetic mechanisms gradually increased, until, with the emergence of symbolic modes of communication, *Homo sapiens* has become that evolutionary *rara avis*—a predominantly cultural animal. Nonetheless, as modern research indicates, our capacity to increase and transmit learned behaviour is still and always has been and will be ultimately dependent on phylogenetically evolved capacities. It thus becomes apparent that culture is a purely natural phenomenon, and has developed in continuous interaction with phylogenetic processes to become the prime biological adaptation of our species.

It is, moreover, our unique evolutionary history which has made us the 'embodied paradox' that we are; for man, in behavioural terms, is a kind of evolutionary compendium, with mechanisms in the phylogenetically old parts of his brain, such as his reticular formation and limbic system, which he shares with vertebrates as meagre as lizards and as excitable as the chimpanzee; while in his neo-cortex are neuronal circuits which confer on him the capacity to engage in symbolic behaviour and to exercise preferences—so that he becomes like a god, having knowledge of good and evil. This capacity to exercise preferences has gradually emerged in the course of human evolution in close conjunction with the capacity to symbolise, to recall the past and envisage the future,

[93] L. S. B. Leakey, 'Development of aggression as a factor in early human and pre-human evolution', in *Aggression and Defense (Brain Function, Vol. 5)* (Berkeley and Los Angeles, University of California Press, 1967), p. 7.

and so has given to man a freedom of action, limited though it be by inexorable natural processes, that far excels that of any other animal organism. And with this freedom—as the brief chronicle of our recorded history shows—human individuals have soared to sublime heights and descended to disastrous depths.

We are here confronted with the phenomenon of human values, for values are a function of the capacity to exercise preferences, and so, ineluctably, become a part of the subject matter of evolutionary anthropology, as, indeed, of any discipline that concerns itself with human behaviour.

In the words of the American biologist Herrick: 'Man's capacity for intelligently directed self-development confers on him the ability to determine the pattern of his culture and so to shape the course of human evolution in directions of his own choice. This ability which no other animals have, is man's most distinctive characteristic, and it is, perhaps, the most significant fact known to science.'[94]

The truth embodied in these words has now, I believe, become apparent to very many scientists; moreover, concern with values is intrinsic to what Bronowski has called 'the culture of science'. We can practise science, as Bronowski reminds us, 'only if we value the truth'.[95] By valuing the truth, scientists make radical discoveries about the determinisms of nature, which inevitably extend the range of choices open to men, and so create situations in which concern with values is inescapable. Indeed, I would argue that it is only when he understands something of the determinisms of nature, including, most importantly, the determinisms of his own body and brain, that a man can begin to become truly and humanly free. As René Dubos has so well expressed it: 'Man makes himself through enlightened choices that enhance his humanness'.[96]

What then are the prospects for a science of human values? First, it will be necessary to transcend the doctrine of cultural relativism which denies even the possibility of any broadly-based evaluation of human choices, by asserting, as it does, that differing forms of cultural behaviour or shared preference are normal *sui generis*, and so cannot be compared in biogenetic or any other terms.

Fortunately, the biological sciences have something better to

[94] C. J. Herrick, cited by Robert B. Livingston in *The Neurosciences*, p. 500.
[95] J. Bronowski, *The Identity of Man* (New York, Natural History Press, 1965), p. 100.
[96] Dubos, *So Human an Animal*, p. xii.

offer us. Basic to the science of evolutionary biology is the phenomenon and concept of adaptation. Simpson, Pittendrigh, and Tiffany have defined an adaptation as 'any aspect of the organism which promotes its welfare, or the general welfare of the species to which it belongs, in the environment it usually inhabits'.[97] Fundamental to this definition is the notion of welfare, and it is apparent, in the light of much cumulative experience in the biological sciences, that no adequate analysis of the evolutionary process is possible without the concept of adaptive value.

Further, concomitant with this fundamental biological phenomenon of adaptation is the phenomenon of organic diversity, for adaptation and diversity are equally the products of evolution by natural selection. Moreover, this diversity of animals and their behaviour exists both among species and between individuals within the same Mendelian population.

From these natural characteristics of populations of living things, we are able to derive the fundamental principle of *adaptive diversity*, and it is this principle, I would suggest, that must guide any science of human values, for it provides us with the soundest of biological foundations—*the positive evaluation of diversity whenever it is adaptive*—this being the value inherent in evolution by natural selection and so in the life process itself.

The analysis of the diversities of human behaviour in terms of their adaptive value must depend, it is plain, on a unified scientific understanding of the natures and situations of human beings. This scientific understanding, which we have been seeking for so short a time, is still very limited, but it is now progressing faster and more fundamentally than ever before in our extraordinary history as a species, and from this we can take hope.

But let us also hope that those who become involved in the scientific study of values will not neglect the wisdom of their precursors, who, down the ages, have given concern to the nature—ever-changing as it is—of human values.

On a wall of one of Canberra's high schools someone has written: *God is dead.* Beneath it a juvenile wit has added the words: *No, he's not, he's alive, and doing a science course at the Uni.* This experience, I have little doubt, would be edifying to many of the

[97] G. G. Simpson, C. S. Pittendrigh and L. H. Tiffany, *Life: an Introduction to Biology* (New York, Harcourt, Brace, 1957), p. 434.

gods of which men have so far conceived, but I am constrained to wonder whether some of man's gods, if only in the sense of symbolic projections of species wisdom about adaptive values, might not have something of importance to tell some of the scientists.

One of the most memorable of William Blake's poems begins:

Tyger! Tyger! burning bright
In the forests of the night,
What immortal hand or eye
Could frame thy fearful symmetry?

And Blake goes on to ask:

Did he who made the Lamb make thee?

We now know that it was the evolutionary process that made the Tyger burning bright, as it made us; but to me as a student of human evolution, one of the most notable of evolutionary phenomena is that the human species, ascended as it is from impulsive, predatory, and carnivorous apes, should have produced behavioural innovators, whatever their quirks, such as Hammurabi and Confucius, Akenaton and the Buddha, Jesus (for Blake's Lamb has a capital L) and Francis of Assisi, who, with his awareness of the interdependence of living things, might well be adopted (as an American historian has recently suggested)[98] as the patron saint of ecology.

Such an ethic of concern for the welfare of others, which is comparable to the Buddhist value of heedfulness, is gradually becoming part of a scientific and humanistic attitude towards human existence, and a true scientist must, I believe, while not abandoning the mechanistic *Weltanschauung* (which has contributed so markedly to the scientific understanding of biological phenomena), come to adopt such an attitude of informed concern towards the life process in all its aspects, for without such human values, as W. H. Auden has reminded us, 'no secular wall will safely stand'.[99]

What we can rationally hope for, then, is the emergence, within the next few decades, of a unified science of man and his behaviour, grounded on evolutionary biology, and drawing on the universe of relevant scientific knowledge, while remaining cognisant of evolving human values in their adaptive diversity.

[98] L. White, 'The historical roots of our ecologic crisis', *Science* (1967), **155**: 1207.
[99] W. H. Auden, 'Vespers' in *Collected Shorter Poems, 1927–1957* (London, Faber and Faber, 1966), p. 335.

When geneticists, neuroscientists, ethologists, and ecologists, can sit down with archaeologists and historians, psychologists and anthropologists, to work together, using a common scientific and human language, to illumine the evolutionary history and the natures and cultures of men, the day of such a unified science of man will have dawned. That day, I hope and believe, is not far distant.

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