J. Social Biol. Struct. 1986 **9**, 67–89

The unit of replication in socio-cultural evolution

Martin Stuart-Fox

Department of History, University of Queensland, St. Lucia, Queensland, Australia 4067

The last two decades have witnessed a sustained renewal of interest in the application of Darwinian evolutionary theory in the social sciences, most notably to the historical development of culture. Sociobiology has provided a powerful impetus to this trend, but contributions have also come from a variety of other disciplines (Campbell 1965; 1975). The common basis for such interest lies in recognition of the need to situate the evolution of man, including the evolution of human behavior and culture, firmly within an overall biological context, while avoiding the pitfalls of earlier attempts, e.g. those of Spencer (1972 [1873]). To this end a number of hypotheses have been advanced extending the twin Darwinian principles of variation and selective retention to provide the common theoretical basis necessary for both biological and sociocultural evolution to be subsumed within a common evolutionary theory. Notable contributions to a Darwinian theory of sociocultural evolution have come from Campbell (1965), Hill (1971), Ruyle (1973), Cloak (1975), Richerson and Boyd (1978), Durham (1979; 1982), Mundinger (1980), Pulliam and Dunford (1980), Plotkin and Odling-Smee (1981), Cavalli-Sforza and Feldman (1981), and Lumsden and Wilson (1981).

While these various theories differ in the extent to which they envisage biogenetic and sociocultural evolution interacting in the development of human societies and cultures, all agree on the essential mechanism by which the evolution of culture must proceed: selective retention of a variable 'unit of culture'. By analogy with the gene in biogenetic evolution, some 'unit of culture' is taken to be the elemental means by which culture is both replicated and transmitted. Such a unit must be able to be transmitted and be open to variation (mutation). Therefore, in the final analysis, it must be particulate. But while these properties have been widely recognized, there has been little or no agreement on just what constitutes a 'unit of culture'. Numerous suggestions have been made – 'traits', symbols, ideas, concepts, 'memes', 'culturgens', etc. – but none has found general acceptance. Indeed in a recent assessment of current theories of sociocultural evolution. Daly states flatly that there is still *no* cultural analogue for the gene (Daly, 1982: 402).

The identification of the unit of replication in sociocultural evolution is not simply of importance for its own sake: on it depends any real progress in developing either an evolutionary theory of social change, or a coevolutionary theory linking biogenetic and sociocultural evolution. What Bronowski stated in 1977 still holds true, despite advances since then: 'we do not know the mechanism for social change because we have not been

0140–1750/86/010067 + 23 $03.00/0

able to pin down the units with which it works. . .' (Bronowski, 1977: 157; quoted in Baldwin & Baldwin, 1981: 255). The importance of isolating the mechanism of sociocultural evolution has been frequently stressed (e.g. by Huxley, 1956; Burnham, 1971; etc.), which makes it all the more surprising to find Richerson and Boyd arguing that 'The precise *mechanism of inheritance* of the code is likely to be largely irrelevant so long as the purpose of the code is to generate phenotypic behavior (adaptations). . .' (Richerson & Boyd, 1978: 132, their italics). On the contrary, the precise mechanism is of crucial importance because, unlike biological evolution after *The Origin of Species* but before the rediscovery of Mendelian inheritance, the mechanism of sociocultural selection is yet to be adequately theoretically specified (for early attempts see Hill, 1971; Durham, 1976; and Mundinger, 1980). It seems unlikely therefore that sociocultural evolution could make the kind of progress biological evolution did before it developed an understanding of the mechanics of inheritance. Instead, progress in the theoretical understanding of sociocultural evolution is as likely to come through the reverse process. Definition of the unit of replication could help to clarify the processes(es) of selection. This seems the more likely since the model for an analogous theory of sociocultural evolution is not Darwin's theory of natural selection: it is the modern synthetic theory of evolution with its well developed genetic basis. Thus I would maintain that theoretical progress in understanding the mechanism of cultural change, if this is to prove to be functionally analogous to that operating in biological evolution, depends on identifying a 'unit of culture', aspects of whose behavior can be shown to be analogous to that of the gene. Without this, no theory of cultural evolution seems likely to gain general acceptance.

It seems to me there are a number of reasons for the difficulties encountered in isolating a unit of cultural replication. One reason has been the theoretical disparity between evolutionary biology and the study of sociocultural evolution. While biologists have developed reductionist genetics on a firm quantitative molecular foundation, social scientists have been unable to agree on a common theoretical basis for the sciences of man. Sociobiologists have concerned themselves only with the macroevolution of societies and cultures (Parsons, 1966; Sahlins & Service, 1960), while cultural anthropologists, beset by competing paradigms (functionalism, structuralism, adaptionism), have had difficulty even defining their central focus of interest (what is culture?), and thus what it is they are trying to explain (cf. Keesing, 1974). As a result, the theoretical sophistication of population genetics encouraged biologists to seek analogous mechanisms in the domain of culture change – but without proper prior analysis of how culture actually is replicated and transmitted. This failure to focus analysis on how culture is replicated is another reason why it has proved difficult to isolate a 'unit of culture'. It has meant that the role of mind in the replication of culture has been insufficiently recognized, and that the relevance of developments in modern psychology for the study of sociocultural evolution, especially in the fields of social, developmental and cognitive psychology, have not been adequately appreciated. With few exceptions (eg. Pulliam & Dunford, 1980) even learning theory has been underestimated as a source of relevant and useful research findings.

This paper sets out to isolate the unit of cultural replication. It takes for granted (a) the scientific status of the synthetic theory of evolution[†] and (b) that this theory provides the most likely model on which to base a theory of cultural evolution[‡]. It also

[†] The change of heart by Sir Karl Popper (cf. Popper, 1961; 1972) has lent powerful support for the status of evolutionary theory. It has also been ably defended by such scholars as, e.g. Williams (1973), Campbell (1978), Grene (1981) and Ruse (1982).

[‡] Recent attempts to modify the synthetic theory of evolution by e.g. Gould (1980), Reidl (1977), do not threaten the key processes of variation and selective retention. They merely maintain that greater account should be taken of additional processes operating to bring about speciation and macroevolutionary change.

takes for granted that culture evolves in response to environmental pressures, and that changes which occur are broadly adaptive in a biological sense, i.e. in terms of increasing individual inclusive fitness – both points are made frequently by a number of authors (e.g. Durham, 1982; Flinn & Alexander, 1982)†. The paper begins with a brief discussion of what is meant by culture, three aspects of which are distinguished – the material, behavioral, and mental. In the following section, the process of culture change is examined, with special attention given to the role of the individual in the replication of culture. The conclusion is reached that any unit of cultural replication must be identified at the level of the individual human mind. In the next section the function and structure of mind is examined with a view to determining its role in the individual appropriation and modification of culture. In the light of the foregoing discussion, previous attempts to define the unit of replication in cultural evolution are critically examined, and a new definition is offered.

Culture: material, behavioral and mental

Any attempt to define more precisely the unit of replication in cultural evolution must begin with an analysis of what is meant by culture. Culture has been defined in a bewildering variety of ways (see Kroeber & Kluckholm, 1952; Schneider & Bonjean, 1973; and for an evaluation, Keesing, 1974). In its broadest sense culture has been taken to include not only the 'knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society' of which Tylor wrote (Tylor, 1871), but also every form of human behavior and every artifact that human beings have produced as a result of that behavior – so-called 'material culture'. This latter 'wondrous and gargantuan category' takes in, as Schneider points out (Schneider, 1973), every conceivable item, including the kitchen sink. Various attempts have been made to define 'culture' more narrowly, in the belief that a concept which incorporates ideas, behavior, institutions and things in one conglomeration lacks the sharpness and clarity necessary if it is to be useful as an intellectual tool. However, anthropologists have failed to agree on how the concept of culture should be narrowed and refined – some have even pronounced it undefinable (Bohannan, 1973).

One approach to the problem of what constitutes culture is to examine the relationship between its component parts. Culture in its broadest sense can be seen as having three aspects: (a) material culture, (b) behavior, and (c) culture as it is mentally appropriated by an individual – 'the form of things that people have in mind, their models for perceiving, relating, and otherwise interpreting them' (Goodenough, 1957; 167). Analyses of what is meant by culture have tended to emphasize one or another of these three aspects. For example, Flinn and Alexander appear to see culture largely in material terms. They note that culture 'results from the inclusive-fitness-maximizing efforts of all humans who have lived': it is 'an aspect of the environment into which each human is born and must succeed' (Flinn & Alexander, 1982: 397). Marxists also emphasize the material aspect, the products of culture. Yet an anthropologist like Harris, despite his 'cultural materialism', identifies culture principally with behavior (Harris, 1968). Bonner defines culture as both information and behavior. Culture is, he says, 'the transfer of information by behavioral means, most particularly by the process of teaching and learning' (Bonner, 1980; 10). Goodenough, on the other hand defines culture entirely in

† Culture was long recognized as adaptive (cf. Alland & McCay, 1973; Buckley, 1968) before this was explained in purely sociobiological terms (cf. Alexander, 1979; Irons 1979, etc.).

mental terms as 'whatever it is one has to know or believe in order to operate in a manner acceptable to [a given society's] members' (Goodenough, 1957; 1971; see also Murdock, 1960).

Several scholars combine two or more of the three aspects of culture in their definitions. Thus Bohannan has suggested that culture comprises both ideas and behavior (Bohannan, 1973); and Mundinger defines culture as a combination of mental, behavioral and material elements: 'a covert population of acquired neural codes' together with 'an overt population of functionally related, shared, imitable patterns of behavior (and any material products produced)' (Mundinger, 1980: 191). Clifford Geertz has attempted to bridge the divide between culture as behavior leading to material transformations (Harris) and culture as ideas (Goodenough) by stressing the importance of culture as communally understood meaning, i.e. as something shared by members of a society in social interaction (Geertz, 1973). Culture for Geertz, then, is essentially shared meaning, something only possible in a social setting: it is not so much the expression of individual minds as a characteristic of social systems.

Geertz's conception of culture brings out one of the major problems any analysis of what is meant by culture must face: the relation between individual and communal or group culture. An analysis of this relationship provides an opportunity to move from a static to a dynamic approach to culture; from definition to an examination of how culture is replicated. At the individual level, the three aspects of culture noted above – the material, behavioral and mental – interact in the following ways: whereas behavior presupposes for its expression certain individual mental acts (the neural basis for behavior), material culture depends upon both behavioral *and* mental aspects. For a cultural artifact (a basket, a book) to be made, people must behave in certain ways, and such behavior presupposes certain mental states. When an artisan merely copies a new artifact, he has first to examine it, to conceptualize the relation of its parts, to note how it differs from forms he has previously made, in order to arrive at some idea how to go about making it. A similar process applies when behavior is imitated. A mental act still precedes habitual behavior: a decision must be made to perform a given habitual action a certain number of times. Only a reflex action requires no prior mental act, but such actions play no part in the creation of culture. Of the three components of culture, therefore, the mental is the most basic in the sense that it underlies both other aspects of culture: in the last analysis, culture is dependent upon the activity of human minds.

But, it may be objected, culture is more than the sum of individual mental, behavioral and material parts: culture is a group phenomenon. It is, as Geertz would maintain, a product of social interaction. I agree. Even in the least complex primal societies individuals cooperate with each other in the production of artifacts and the performance of rituals. In a modern industrial society even the simplest artifact requires the labor of many people for its production, distribution, and marketing, each of whom contributes a specialized skill which depends upon knowledge held in the mind of that particular individual. This knowledge forms part of the individual mental culture of that person, his private culture or 'propriospect' (Goodenough, 1971: 36)†. It may be, in the case of a complex modern implement such as an electrical appliance, that no individual has all the necessary knowledge and mechanical skills to enable him or her to produce that

† Goodenough defines propriospect as an individual's 'private, subjective view of the world and its contents – his personal outlook' (Goodenough, 1971: 36). He goes on to list no fewer than seven kinds of culture differentiated in terms of group size (from individual to group to society as a whole) and whether or not the values, standards etc. which he takes to comprise culture are subjectively held or objectively expected of others (Goodenough, 1971: 41–42).

artifact. But that does not alter the fact that its production is the outcome of individually assimilated knowledge.

In stressing the individual basis of culture I am not denying either the existence or the importance or higher level social entities (associations, organizations, governments, etc). Nor am I espousing a radical methodological individualism in explanation of social change. The structure and behavior of higher level social entities can usefully be discussed in their own terms. What I do maintain, however, is what too many social scientists apparently overlook, and that is that all such higher social entities are composed of individuals and the social entities they comprise must be taken into account.

How then does individual culture relate to group culture? The relationship of the latter to the former is not as we have seen, one of simple summation, for it is the interaction of parts which creates the whole. The individual learns in a cultural context comprising a material environment formed by the behavior of previous generations, a context which is changing as a result of continuing behavior and material production. The mental appropriation of culture by each individual constitutes no more than a selection from the potentially available communal culture. Since communal culture results from the interactions of individual cultures, its totality is necessarily greater than any individual part. Overall communal culture may be conceptually appropriated, but never in totality; only as an abstraction in the cognition of an individual, as a term of reference, or a model of interaction, as an anthropologist might conceptualize the culture of a primal society (cf. Tyler, 1969: 5). Changes in and additions to individual mental culture occur through continuing interaction with the overall communal cultural context which is itself always in flux. Processes of growth of both individual and overall communal culture are thus mutually dependent.

The above analysis does not constitute a definition of culture, nor do I propose to give one. My concern is not to provide a static definition of culture, but with the dynamics of how cultures are replicated and evolve. What is important to note from the above analysis is first that culture is both individual and communal, and second that it consists of three interlocking aspects -- mental, behavioral, and material. Also, while individual culture comprises all three aspects, communal culture consists of only two. There is no communal element equivalent to mental culture. The source of group behavior lies in individual minds each reacting similarly to the same stimulus: there is no such thing as a 'group mind'[†]. Thus for a complex communal culture to continue from generation to generation, individual minds must internalize varying selections from that culture and, in acting together, maintain and modify it. This process of selection takes place through learning. It results in minds shaped predominantly by parental influence, together with a combination of various other influences – teachers, peer groups, reading, television, etc. Each selection will be different: no mind is the exact replica of another. And each individual acts on the basis of his or her own selection. Thus the individual is the key to any understanding of how culture is replicated, and must be central to any theory of cultural evolution (cf. Durham, 1982).

[†] It would be possible, however, to abstract from the set of individual mental cultures those beliefs, values, interpretations, etc. which are common to all, and thus, could be said to characterize the culture of the group. This is the sense in which the *weltanschauung* ('world view') of a society was used by Dilthey (Bulhof, 1980) and taken up by anthropologists (Kearney, 1975). Habermas goes so far as to argue that homologies can be found between the development of both individual cognition and ego development, and the evolution of the world view of a society (Habermas, 1979; 102–106).

The replication of culture

The role of the human mind in the transmission and modification of culture becomes evident when we turn to examine *how* culture is replicated. For the anthropologist, interest has focussed on culture as a system, and on the ways in which the parts relate to the whole. This has encouraged a functional or structuralist approach to the study of culture that has often minimized the importance of culture change. By contrast, the theorist of cultural evolution must focus on how cultures are replicated and modified over time.

I want to look first at how a material item of culture is replicated. Take the example of an earthenware pot. The potter's son who learns to make pots identical to those made by his father inherits part of his father's individual culture. At the same time, since those pots are used by his cultural community, the potter's son also contributes to the replication of communal culture. Now as noted above, in order to make a pot a series of mental acts have to be performed which translate into behavior. As the potter's son becomes a skilled artisan most such mental acts will become habitual: making a pot will become 'second nature'. But that does not mean that the potter's actions in making a pot have not been consciously learned: his behavior still depends upon prior mental acts.

The primacy of the mental level of culture is also evident from a consideration of how innovations come to be adopted. Suppose a new shape of pot is introduced into a community (by 'cultural diffusion', trade, plunder, migration, etc.). The pot will remain a curiosity unless someone can conceive a use for it, and asks the potter to make another. The use to which the pot is put in the receiving culture may not be the same as its use in its culture of origin, but only if some use for it can be conceived in the receiving culture will it be replicated in that culture. The role of mind in the replication of culture is clearly essential. Any new behavior to become established requires a prior conceptual innovation, and its subsequent expression in innovatory action. It does not matter if a conceptual innovation in the receiving culture does not exactly replicate any conceptions held in the culture of origin, *some* mental act is essential if innovatory behavior leading to the production of a novel cultural artifact is to become established. The potter himself may not appreciate the advantages of a new form of container: he may prefer the traditional shape. But he will copy the new shape if rewarded for doing so. Prior mental acts are just as essential to this production process as they were when the potter learned from his father to copy traditional pots[†].

To sum up: it does not matter how a new item of culture is introduced, whether it be by importing material objects, migration of a skilled craftsman, or the communication of ideas. For an innovation to find a place in a receiving culture it must be appropriated by individual human minds. And the role of mind is equally central in the replication of even the most static culture. Only if the next generation can learn during the course of mental development how an item relates to others in the overall culture in some accepted, useful or significant way will that item be retained as part of that culture. No aspect of material or behavioral culture can be replicated without the intervention of the human mind.

I have placed considerable emphasis on the central role of mind in the replication of culture only because some cultural evolutionists have argued that cultural artifacts 'reproduce' themselves through the continuance of basic forms or blueprints (Medewar, 1975; Boulding, 1978; but cf. criticisms in Wheeler & Danielli, 1981). Cars and aeroplanes

[†] The importance of observational learning has been stressed by social learning theorists such as Bandura (1977). For the diffusion of cultural innovations, see Schon (1963), Barnett (1953) and Rogers (1976).

and washing machines are all said to have basic designs which 'evolve' when factories turn out new models. Organizations too are said to 'reproduce' themselves through maintaining continuity of structure. Individuals may be hired or fired, but the division and relations of labour are broadly maintained. However, this conception of artifact or organization reproduction only leads to misunderstanding and confusion.

Part of the confusion over how items of culture are reproduced arises from the use of unacceptably loose and metaphorical language. Use of the very term 'reproduction' in talking about the cultural transmission of cultural traits or artifacts is probably the most misleading example of this. Reproduction is a biological process which is central to biological evolution, and to use it of cultural items incapable of reproducing in the way that living organisms do is needlessly to confuse the process by which such items are replicated and their use extended throughout a particular culture. This it does by obscuring the role of the human mind, for the fact remains that cultural phenomena depend for replication on the mediation of mind – even in the case of 'mindless' imitation, or when, as in the case of computer directed machine tools, there is no direct human involvement in the process. Machine tools, computers etc., all require prior programming by a human mind before they can replicate any given artifact, and a human decision to set them working.

Neither material items nor organizations comprise 'species' by which, through the agency of selection of variant forms, societal evolution takes place. Whether we are discussing simple products of technology (a stone axe, for example), or complex, organizations, both depend for their replication on appropriate human behavior. When artifacts change over time (new models are produced), they do so because human behavior has been modified; and when organizations either are conserved in the face of pressures for change, or change in answer to such pressures, they do so through the actions of the individuals who form those organizations.

Given that the evolution of cultural artifacts depends on changing patterns of individual human behavior, cultural evolution could perhaps be conceived in terms of selective variation of behavior. It could be argued that change in behavior may be transmitted through conscious learning or unconscious imitation, to become characteristic of a given culture at some new phase in its development, as when chipping to produce an axe blade gave way to grinding. Particular aspects of behavior could be observed, described and related to overall cultural patterns, with a view to defining unit variations in behavior as a basis for selection. But apart from the difficulty of describing any culture in purely behavioral terms, and the virtual impossibility of defining 'units of behavior', this approach also fails to take account of the relation between behavior and underlying mental states. Behavior should rather be conceived as providing the link between individual mental culture and continuing production of the material culture of the community. Behavior thus constitutes the cultural analogue of those biochemical transmitters and interactive processes which translate the instructions of the genes during the development of a biological organism. The biological sequence genes → transmitters → phenotype can thus be taken as a model for the analogical cultural sequence 'cultural genes' (given that these are located in the individual mind) → individual behavior → material culture, bearing in mind that just as *both* the biochemical transmitters and resultant morphological structure and/or behavior are phenotypic expressions of the genes, so *both* the behavioral and material aspects of culture are phenotypic expressions of the mental aspect of culture as this is appropriated in individual minds†.

† Bock maintains that such material constructions as birds' nests and spiders' webs 'are properly included in the phenotype of these organisms' (Bock, 1978: 408). Steward was among the first to refer to cultural behavior as 'phenotypical' (Steward, 1960).

We are brought, therefore, to consider the mental component of culture, and to see whether it is possible for variation at this level to be selectively appropriated and expressed in such a way as to bring about overall cultural change. In so doing, however, we shall confine attention to individual culture, for it is only at this level that the mental aspect of culture is located: let me reiterate, there is no such thing as the 'group mind' of a society giving rise to 'communal culture'. Communal culture is the result of the interaction of the mental, behavioral and material aspects of individual culture: changes in the former depend upon change in the latter. At this point it is useful to recall the biological model for which we seek a cultural analogue – in particular the way in which genes translate into organic structures. Just as the genes an organism is born with, in interaction with environment, determine its morphological structure, so the cultural analogues of genes should be thought of as shaping the structure of individual culture. If we seek the cultural analogue of genes in the mental component of individual culture, it should be possible to show that these 'cultural genes' in some sense structure the mind of each individual. Any attempt, therefore, to define more precisely what might constitute the cultural analogue of the biological unit of replication must begin by examining more closely the structure of the cognitive content of the human mind. To this we now turn.

The function and structure of mind

The biological function of the brain as it has evolved in animal species, has been to internalize perceived environment in order to facilitate responses to it. The human mind has evolved the further capacity to plan responses to environmental contingencies by symbolically previewing alternative courses of action. This is does through building up a picture of how the world (for any individual) is constructed and works. P. N. Johnson-Laird in a recent study of how the mind works, argues that 'all our knowledge of the world depends on our ability to construct models of it' (Johnson-Laird, 1983: 402). Mental models are, he says, 'structural analogues of the world': they are both functional and symbolic. They are not, however, the only kind of mental representation. 'Propositional representations' are 'strings of symbols that correspond to natural language'. They can be mapped into mental models by a process which designates a single model as representative of the set which would satisfy a particular assertion (p. 264). In fact Johnson-Laird maintains that construction of such a model, which is open to recursive modification, constitutes comprehension of the assertion. Images are 'perceptual correlates of models from a particular point of view' (p. 165), which may be more or less vivid, detailed, etc. They constitute a sub-class of mental models. By means of manipulation of mental models we conceive the world as a basis for action, interpret language and make inferences. As Johnson-Laird puts it

> mental models play a central and unifying role in representing objects, states of affairs, sequences of events, the way the world is, and the social and psychological actions of daily life. They enable individuals to make inferences and predictions, to understand phenomena, to decide what action to take and to control its execution, and above all to experience events by proxy; they allow language to be used to create representations comparable to those deriving from direct acquaintance with the world; and they relate words to the world by way of conception and perception (Johnson-Laird, 1983: 397).

Mental models are composed of elements whose structural relations constitute an essential part of its symbolic significance. As Johnson-Laird says: 'The structures of mental models are identical to the structures of the states of affairs, whether perceived

or conceived, that the models represent' (p. 419). This structure is built up through the relations connecting the 'tokens', or symbolic elements, included in the model. Such models are either physical or conceptual. Six types of physical models are identified: relational, spatial (a sub-class of relational models in which all relations are spatial), temporal (a sequence of spatial 'frames'), kinematic (a temporal model that is psychologically continuous), dynamic (a kinematic model which includes causal relations between its elements), and images. Conceptual models are more complex, more highly symbolic. Unlike physical models, they can represent true, possible or imaginary situations. Johnson-Laird identifies three types: monadic, relational and metalinguistic. All include abstract relations between entities.

The mental models in which Johnson-Laird is interested are those of which we are conscious in interpeting language, comprehending discourse, or making inferences. But these models, even those that result from immediate perception, draw upon long-term memory for their meaning and context. The processes of thinking, planning, decision making etc., depend entirely on the retrieval of mental models from the storehouse of memory. Memory can therefore be said to comprise the set of all such retrievable mental models. The structure of models retrievable reflects the structure of memory that gives rise to them. Relations between the symbolic elements in a mental model are relations which pertain between elements retained in memory. The total structured content of memory (which cannot, of course, ever be brought to consciousness as a whole) constitutes the 'world model' of an individual†.

Such a picture, or 'world model', consists of more than a spatial mapping of physical environment: it includes temporal and causal relations, and it includes, most importantly, relations of meaning. Meaning-relations are the connections which define the meaning given to a mental representation in an individual world model. They may be socially sanctioned (e.g. the dictionary definitions of words), or comprise an individual affective component derived from experience, but they are always connections with other such mental representations, for the meaning of any symbolic element depends entirely on the context in which it is situated. The semantic structure of mind is built up through additions to the meaning-relations between perceptually or conceptually differentiated elements [the 'links' in node–link models of the semantic structure of long-term memory (Simon, 1979: 376–378)]. The cognitive content of mind may thus be conceived of as structured by the meanings which an individual has learned to attach to relations between conceptual representations of the physical and social environment in which he or she exists (cf. Johnson-Laird, 1983: 196–203). Such meaning-relations are built up during the lifetime of an individual through both personal and vicarious experience. Together they comprise the understanding an individual has of the world, his or her psychological construction of reality, or world view, as this is held in long-term memory‡.

A perceptually differentiated item in the environment is conceptually located as a component of world view through the building up of meaning-relations with other such

† This seems to me a more satisfying account of mental structure than for example the assemblage of 'cogits' proposed by Hayes-Roth (1977). It gains powerful support from computer simulation models. Herbert A. Simon concludes from a recent assessment of work in this field that human long-term memory is most likely to have a node–link structure [Simon, 1979: 378; cf. also the surveys in Smith (1978) and Wickelgren (1981)].

‡ Berger states that world view 'is at once a man-made persective *on* reality and configuration *of* reality' (Berger, 1972: 00; his italics). Lieblich and Arbib (1982) prefer the term 'world graph'. De Mey refers to a plurality of world views (de Mey, 1982: 255–257). This is misleading. I would prefer to use 'world view' in the anthropological sense to refer to the overall structure of cognitive content (cf. Kearney, 1975), and 'schemata' or 'frames' ['data structure for representing a stereotyped situation' (Minsky, 1975: 212)], to refer to those cognitive substructures which the mind draws upon to process particular types of experience (cf. Goffman, 1974; Simon, 1979).

mental representations. New meaning-relations, by modifying or conflicting with earlier ones, lead to changes in semantic structure. At all stages in mental development, existing structure both orders and is modified by newly learned meaning-relations. To give an example: the Afghan nomad who sees his first motor truck when it nearly runs him over, incorporates it into his understanding of the world as a threatening object to be avoided, perhaps the work of a *djinn*! Later while recounting his experience, he may learn from an itinerant merchant that a truck can be useful in transporting himself or his animals. A more complex conception of a motor vehicle is thus built up through a combination of new meaning-relations, one which weakens, then finally undermines, the initial meaning-relation conceived to exist between truck and devil. In this way understanding evolves through the building up of a set of meaning-relations linking the representation of the object in question to others in the existing mental universe of the experiencing actor (cf. Johnson-Laird, 1983: 204; Brown, 1973: 200) The degree of abstraction (remoteness from experience) of any level of understanding is a function of the number of hierarchic levels separating it from basic perception (cf. Layzer, 1980: 240).

At a basic level components of world views are shared: they are a function of being human. Allowing for physiological disorders, individuals interiorize their material surroundings in similar ways because they possess similarly functioning organs of perception. Thus there is usually general agreement that an object is of certain dimensions, standing in such and such a spatial relationship to other objects, etc. Even animals appear to form spatial representations or maps of their physical environment in order to respond to it (Griffin, 1982: 356–359). But the human mind does more than that. It forms mental representations of how the world works. This enables human beings not simply to react to the environment, but to act upon it to change it through the creation of material culture. This semantic content of mind is superimposed on and interrelates with spatial representation through the naming of items in the environment and the relations between them[†]. Different cultures attach different linguistic symbols to the same object; but these are equivalent to the extent that translation between languages is possible. What differentiates one mental representation of an object from another is the set of meaning-relations which link it with other representations. The tree which is nothing but a tree for the Western tourist is the home of a powerful spirit for the Thai peasant. And this difference is *cultural*. Individual world view, the structure of meaning-relations linking mental representations in long-term memory, thus constitutes *individual mental culture*.

The mental structure which comprises the 'conceptual space' of a world view is made up of two sets of components: representations (mental symbols) of perceptually or conceptually differentiated items named within a given linguistic and cultural tradition, and the meaning-relations which both link these representations and together constitute the overall significance of each. A distinction should be drawn between the linguistic definition, or shared communal meaning, given to a particular named representation or named relationship between representations (I *like* this book), and the subjective meaning each individual additionally attaches to representations as a result of his or her own personal experiences. Both communally sanctioned and individually added

[†] Hence the interaction between mind and perception that Gombrich and Gregory have emphasized (Gregory, 1972; Gombrich, 1982). On spatial mapping see O'Keefe and Nadel (1978), Lieblich and Arbib (1982) and Kaplan (1973). Kaplan maintains that the way in which mental structure represents spatial relations is no different from that underlying all cognition of representations (Kaplan, 1973: 74). Similarly, he maintains that the mental framework for immediate decision making is essentially the same as that for contemplative thought (p. 75). If this is so, research into relatively simple mental structures underlying spatial representations and the relations between them can be applied to the more complex structures of cognition underlying abstract ideation.

meaning-relations serve to situate a representation with respect to others in individual world view. Together their 'vector sum' constitutes the significance (meaning plus value) attached to that representation. The notion of 'uncle', though defined by familial relationships, will be given additional meaning through personal relationships with one's own uncles, observation of the ways in which other people's uncles behave, reading about uncles, etc. While formal definitions of meaning are essential for communication, the values which derive from additional personal meaning often play an important role in motivating action, and thus in maintaining or modifying culture.

Meaning-relations derive from a variety of sources. The most important is undoubtedly social communication through language and other means. Other sources of meaning-relations are communally sanctioned values and moral principles which lead to the adoption of attitudes towards particular behaviors, other social groups, etc. The stereotyping to which this all too often gives rise may be reinforced, or modified by personal experience, or by artistically mediated vicarious experience through contact with others, or through literature, art, the theatre, films, and so on.

Each separately conceptually identified mental representation can be thought of as constituting a designated node in the structure of individual world view. The more complex the set of meaning-relations linking any representation with others, the more complex (and in some cases the more ambiguous) the meaning that representation has in individual consciousness. This applies both to representations of items in the environment, and to purely mentally constructed abstractions. Loyalty as unquestioning support of one's feudal lord, is a simpler conception than loyalty which recognizes the demands of conflicting responsibilities. In general it would seem that potential awareness is a function of the complexity of the meaning-relations going to make up a world view (cf. Walsh, 1981). The more aware an individual is of the ramifications of a particular situation, the more meaning-relations interconnect in the mental model the individual constructs of it. These relationships are built up and modified through continuing dialectical interaction between mind and environment: they depend on continued openness to learning, and on the flexibility of already established structures.

The network of representational nodes and meaning-relationships which structure individual mental culture can be conceived of as ordered in a hierarchy of interlocking levels[†]. The ordering of these levels depends on a number of factors: the stage in the individual's cognitive development at which particular conceptions (beliefs) were first established (cf. Bruner, 1956); how deeply embedded they have become in the overall structure; with what conviction affective and axiological relationships are held, etc.[‡]. By determining which relations depend upon which others, the structure of an individual mind can be objectively constructed in the form of a model of progressively more overarching meaning-relationships. The hierarchical relationship between the meaning-relations structuring content of mind in this model is analogous to the hierarchical relationships between different levels of theories in the natural sciences. Another parallel between individual mental culture and scientific knowledge has to do with the essentially

[†]Ketner argues that world views are made up of hierarchies of beliefs (Ketner, 1972). However, Kaplan stresses that representations are connected in networks which are not simple hierarchies (Kaplan, 1973). Clearly the cognitive structure I have suggested is a network model, but one in which certain linking relations stand in a hierarchical relationship to others (cf. de Mey, 1982: 207, 212–215.)

[‡]Mental structure, formed during childhood and becoming relatively stable in adult life (though still sufficiently 'open' to incorporate new experience), provides the continuity necessary for evolution through selection of variation to take place (Bateson, 1972). Layzer argues, rightly, that the constraints imposed by upper hierarchic levels are essential to the 'regulation of variability' which is necessary for psychological wellbeing (Layzer, 1980: 232).

hypothetical nature of the structural units in both – meaning-relations and scientific theories. In both cases subsequent research or learning experiences can prove them to be erroneous or misconceived. But whereas scientific knowledge evolves through the critical testing of hypotheses, meaning-relations, once established, are rarely questioned (Nisbett & Ross, 1980). Where contradictory evidence is available it is all too often either disregarded or rationalized away [cf. theory of cognitive dissonance, Aronson (1969); Osgood (1968)][†]. And yet in the process of building up individual mental culture, there is much room for error. To begin with, as noted above, perception is coloured by previously established structures of mind (including metaphysical assumptions, principles of rationality, deeply held beliefs etc.)[‡] . Meaning-relations may be arrived at through invalid reasoning or lack a proper empirical basis. Where erroneous relationships are compatible with, or reinforce, previously established mental structure, they can all too easily be uncritically integrated into it. Once accepted, an erroneous relation becomes part of the overall world view, and may prove very difficult to rectify. One is reminded of Sartre's comment that you cannot reason with an anti-Semite. Innumerable examples could be adduced both of the conservatism of mental structures (lack of 'communication' between generations, across cultures; or more specifically, inability to accept new theories, or ways of conceiving the world), and of inclusion only of meaning-relations which fit into an already formed structure of mind. Believers in the existence of God see his hand in events which atheists interpret quite differently.

Let me briefly recapitulate my argument thus far. An essential function of the human mind is to preview alternative strategies of behavioral response to environmental conditions, in order that decisions can be made on what course of action to follow. To perform this function I have suggested the mind builds up a cognitive structure in long-term memory comprising more or less complex representational nodes (including not only items from the physical environment, but also abstract concepts, values etc.) connected by meaning-relationships which both define the conceptions held of node items and constitute the structural connections between them. Together representational nodes and meaning-relations comprise a hierarchical structure which constitutes individual mental culture or, in cognitive terms, the world model of the individual. This structure, as it develops, acts as a guiding constraint on the appropriation of new meaning-relationships (learning). It filters, selects, and orders new conceptions and meanings, and serves to guide decision-making and behavior. From it are retrieved the mental models applied in understanding discourse, drawing inferences, etc. This cognitive structure held in long-term memory constitutes the individual's selective appropriation of common culture, his or her individual mental culture. How this model of mental structure might provide a solution to the problem of definition of the unit of replication in cultural evolution now remains to be determined.

Previous attempts to define a unit of cultural replication

The search for a cultural analogue to the gene has been going on at least since formulation

[†] Of course different levels of awareness affect this process in individuals. The development of critical faculties, and the habit of self-analysis, both contribute to the more logical structuring of world view through the identification of inconsistencies and contradictions.

[‡] These include what Collingwood called 'absolute presuppositions' (Collingwood, 1940). See also Pepper (1942), Wisdom (1972) and Hooker (1975). Another approach, following Whorf, would be to examine how language colours observation (cf. Hoijer, 1954; also Jackendoff, 1978). McNeill has attempted to develop a model of the conceptual structure of speech, which he assumes to reflect the underlying conceptual structure of mind (McNeill, 1979). What seems more likely is that language encodes and transmits elements of cognitive structure (cf. Masters, 1970).

of the synthetic theory of biological evolution. Medewar has reminded us that Ewald Hering's concept of the mnene was advanced more than sixty years ago (Medewar, 1981). More recently, with the renewed interest in cultural evolution that has taken place over the last decade, a number of more or less precise analogues have been suggested bearing a number of more or less apposite names. All such previous attempts seem to me unsatisfactory, however, largely because they have not been based upon an adequate analysis of culture and the way culture is replicated.

Previous attempts to define a unit of cultural replication fall roughly into three categories: (1) those in which the units are vaguely defined as cultural 'traits', 'features', 'elements', 'components', or even 'things', all of which seem to have a material basis; (2) those which identify units as behavioral; and (3) those which focus on the mental aspect, either primarily or exclusively.

Many scholars who have treated the unit of cultural replication in general terms as 'traits', 'features', etc. have been careful not to define it further (e.g. Bohannan, 1973: 359–360; Cavalli-Sforza & Feldman, 1981). Such general terms, howeer, set aside the question whether and how it is possible to divide any culture into distinct 'traits' or 'features'; and all leave open the problem of what criteria to use in the delimitation of such 'traits'†. Units of culture so defined are so general as to be all but useless: it is like saying that biological evolution takes place by means of the transmission and differential selection of 'biological traits'.

Definitions which identify the units of cultural replication as 'units of behavior' (e.g. Baldwin & Baldwin, 1981) run into similar difficulties. In addition category two definitions fail to provide a cultural analogue for the important distinction between genes and their phenotypic expression. In light of the above discussion, both material and behavioral definitions may be disregarded.

We turn therefore to category three definitions: those which locate the unit of replication of culture at the mental level. Examples of this kind of definition include two of the most widely discussed named units of cultural replication, Dawkins' 'memes', and Lumsden and Wilson's 'culturgens'. Because these units are frequently referred to, and because both illustrate the kind of conceptual confusion that has marked discussion of the unit of cultural replication to date, both need to be critically examined.

Dawkins says that memes include 'tunes, ideas, catch-phrases, clothes fashions, ways of making pots and building arches'. This is something of a grab-bag: ideas and catch-phrases are part of mental culture; ways of making pots are behaviors; and clothes fashions seem to refer to material items. The net is cast too wide: memes can apparently include any cultural thing. But Dawkins then goes on to state that 'memes propagate themselves in the meme pool by leaping from brain to brain, via a process which, in the broad sense, can be called imitation' (Dawkins, 1976: 206). This would seem to indicate that memes are purely mental units. Presumably, therefore, when Dawkins includes tunes or dress fashions as memes he is referring not to behavior or material items as such, but to ways in which these are mentally represented. However, Dawkins later refers to an organized church as an example of 'a co-adopted stable set of mutually-assisting memes' (p. 212). Here again it seems he is referring to a material cultural item, together perhaps with a collection of individual behaviors. It is all very confusing and Dawkins' definition of an 'idea-meme' as 'an entity which is capable of being transmitted from one brain to another' is not much more helpful. Do other kinds of memes exist? Behavior-memes, for

†Godfrey and Cole (1979) argue against evolution of culture precisely because of the difficulty of defining cultural 'traits'. Cavalli-Sforza and Feldman could avoid defining the unit of cultural transmission more explicitly since much of their mathematical treatment would continue to apply whatever the unit turns out to be.

instance? To claim as Dawkins does that a 'meme' is the cultural equivalent of his concept of the gene, that is, a unit of replication which makes use of the human organism to achieve its goal of maximum propagation, simply substitutes an analogy, and a misleading one at that, for careful analysis leading to a precise definition.

Lumsden and Wilson define their 'culturgen' as 'a relatively homogeneous set of artifacts, behaviors, or "mentifacts" (mental constructs having little or no direct correspondence with reality) that either share without exception one or more attribute states selected for their functional importance or at least share a consistently recurrent range of such attribute states within a polythetic set' (Lumsden & Wilson, 1981: 27). 'Mentifacts' apparently include reveries and dreams, fictions and myths, which the mind reifies and projects as real entities (ibid.: 107–108, 316). They include gods, spirits, totems, etc. (ibid.: 6). A 'pure mentifact' is defined as 'a wholly mental construction based entirely on symbolic or imaginary creatures or objects' (ibid.: 251)†. From the above definition, therefore, it would appear that 'culturgens' are objects which exist or are believed to exist, and thus can be objectively identified as components of a culture. But then we are told that 'culturgens interact with one another in long term memory' (ibid.: 249), something which not only does not follow from the initial definition, but would appear to be specifically ruled out by it. How, one may ask, can physical artifacts – or behavior for that matter – 'interact' in memory? Surely only 'mentifacts' could possibly do that, provided they are not confined to *imagined* mental constructs.

It becomes clear, on a more careful reading, that 'culturgens' have a primary mental component which is ignored in their definition. We are told that a 'culturgen' may be mentally assimilated to become 'a node linked to other nodes and hence part of a broader meaning structure' located in the mind (ibid.: 249). But the relation between 'meaning structure' and behavioral and material culture remains unclear. Does a 'culturgen' have to be mentally assimilated to be reproduced, even if it is a material 'culturgen'? If so, how does this happen? Despite the apparent quantitative precision of their work, Lumsden and Wilson's 'culturgen' remains a remarkably fuzzy concept [cf. criticisms by Caplan *et al.* included in Lumsden & Wilson (1982)].

That ideas are the purely mental equivalent of genes in cultural evolution has been suggested by a number of authors, including Cavalli-Sforza (1971), Ruyle (1973) and Bajema (1978) (cf. Gerard *et al.*, 1956). Other suggestions include symbols (Emerson, 1956; Masters, 1970) and 'rules' (Harré, 1979; Jensen & Harré, 1981), none of which appear to be either particulate or rigorously enough related to either the application of culture or the structure of mind.

One anthropologist who has argued explicitly from an analysis of culture is F. T. Cloak. Culture, Cloak believes, is acquired in tiny, unrelated snippets, which are specific interneural instructions culturally transmitted from generation to generation' (Cloak, 1975: 167–168). These 'corpuscles of culture' constitute what Cloak calls 'i-culture' ('the set of cultural instructions [people] carry in their central nervous systems'), as opposed to 'm-culture' ('the material structures, relationships among material structures, and changes in these relationships which are actually brought about and maintained by behaviors of those cultural instructions'). These 'i-culture corpuscles' or 'cultural instructions' are replicated 'interorganismically', according to Cloak, and by virtue of this are 'more analogous to a viral or bacterial gene than to a gene of the carrier's own genome'.

† Huxley used the term 'mentifact' more consistently to refer to the whole 'psychological framework of culture'. For Huxley, the 'mentifact system' comprised the amount and organization of human awareness'. It constitutes 'a mental microcosm, a system which internalizes the environment, more or less completely and more or less accurately in men's minds' (Huxley, 1956). It is thus synonymous with my individual mental culture.

Cloak then foreshadows Dawkins in claiming that "'our" cultural instructions don't work for us organisms; we work for them. At best we are in symbiosis with them, as we are with our genes' (p. 172).

The term 'cultural instruction' is adopted by Durham (1982) in preference to his earlier use of 'cultural trait' or 'characteristic' (Durham, 1976; 1979). Unfortunately, however, despite Cloak's promising beginning, the term has not been further defined: the behavior of 'i-culture-corpuscles' in the replication of culture has not been clarified, nor has their relationship to structures of mind or cognition. Instead, Cloak has attempted to demonstrate a possible physico-chemical basis for such 'instructions' (Cloak, 1980). But whether or not his speculations along these lines turn out to be neurologically sound, we still need to be given a subjective description of just *what* these instructions are, and how they fit into structured patterns of intentional cognitive behavior (cf. Sperry, 1969). As it stands at present, the term 'instruction' simply camouflages a failure to do this. Furthermore, despite Cloak's insistence that an instruction is 'the unobserved enduring structure or set internal to [a person],' the very use of the word 'instruction' suggests, by analogy with computer programming, a far more closely tied relationship between an instruction and the behavior it produces than is warranted. To this point I shall return below.

Mundinger takes Cloak's 'i-culture corpuscle', labels it a 'meme' after Dawkins, and then extends it to include the behavioral aspects of Cloak's m-culture (Mundinger, 1980: 198). Mundinger uses 'model' (meaning behavioral model) as 'a synonym for m-culture', and affirms that this refers to 'the physical expression of memes' – but offers no explanation of the distinction he is apparently drawing between behavior and material culture, or of what happens to the material aspect of Cloak's 'm-culture'. Memes, for Mundinger, are 'covert, acquired, neural codes', while 'models' are the 'overt motor acts' that these codes produce (how we are not told). Mundinger coins the term 'meme/model pool' as equivalent to Dawkins' meme-pool, and goes on to say that 'meme/model' 'is meant to indicate two aspects of the same unit, like two sides of a coin. This meme/model unit is the replicator of culture' (Mundinger, 1980: 198). This definition is both confused and unsatisfactory: confused because of Mundinger's eclectic dependency on both Dawkins and Cloak instead of on a more careful discussion of what he understands by the replication of culture; unsatisfactory because his definition fails to differentiate the mental from behavioral aspects of culture, which leaves the two combined in a one-to-one relationship and thus fails to make adequate provision for the influence of environment on the expression of memes as models – a mistake which probably stems from Mundinger's over-reliance on studies of animal behavior.

Perhaps the most sustained analogy between sociocultural and biological evolutionary mechanisms advanced to date is that of Hill (Hill, 1971; 1978). Hill sees the gene pool as a specific organic form of a generic 'information pool' whose sociocultural equivalent is a 'concept pool'. Thus for Hill, concepts are the sociocultural analogues of genes. A concept is 'the idea of a class of objects'. It is 'a device by which an individual may classify his environment', and is usually expressed as 'a set of opposed elements' (Hill, 1978: 378). Hill defines concepts as 'oppositions of two or three elements abstracted from the whole and used by an individual to structure a particular situation' (ibid: 379). Concepts do not determine action; but how someone acts 'will depend in part upon how he relates the various factors of the situation to one another . . . through the medium of his concepts' (ibid.: 380).

Hill's concepts represent a genuine attempt to define the units of cultural evolution as comprising an integrated mental structure. My principal criticisms are (a) that the structure is not more clearly defined; (b) that the definition given of a concept and its

relation to social action is not clear; (c) that concepts are not particulate. The first shortcoming results from Hill's dependence on linguistic structuralism and Levi-Strauss, and on his failure to ground his proposed analogue on a proper analysis of the role of mind in the replication of culture. Concepts are classificatory in terms of some common ground between related elements, e.g. hot/warm/cold. But Hill provides no indication how diverse objects might be otherwise related in an individual's cognitive view of the world. The second shortcoming concerns the translation of concepts to behavior via the acting out of roles. Given Hill's definition of concept, I do not understand what he means by saying: 'A role is essentially an element in a concept' (1971: 67). Finally, concepts, as Hill defines them, appear to be variable for different individuals, depending on what 'oppositions' are abstracted. Concepts are constructions of 'oppositions'. They are not particulate, and thus cannot act in an analogous way to genes, combining and recombining as a result of selective retention.

The unit of replication in cultural evolution

I have argued above that the cultural analogue of the gene must be located in the mental component of culture appropriated by an individual. That is, the locus of the unit of replication of culture is the individual mind (cf. Durham, 1982). I have also suggested that individual mental culture can best be conceived of as a structured set of meaning-relations linking both conceptually differentiated mental representations of components of the material and social environment, and mental symbols of such abstract notions as qualities, values, principles etc. Just how these elements in any particular world view are related, and how tightly or loosely meaning-relations are structured, and in what configurations, will be a matter for future research [but cf. that already done by Johnson-Laird and his associates, referred to in Johnson-Laird (1983)].

My model of the semantic structure of long-term memory also distinguishes between the meaning attached to mental representations through culturally sanctioned linguistic classification and definition, and additional meaning, usually emotionally or evaluatively coloured, resulting from personal or vicarious experience. The structure of meaning that results from the individual psychological construction of reality constitutes individual mental culture. How an individual acts in contributing to the continued production of material culture depends on the particular selective appropriation of communal culture represented by his or her individual mental culture.

We are now in a position to define what constitute the particulate units of mental culture, units which are variable at a particular locus (i.e. may both be differentially transmitted, and 'mutate') and which, once selected, both structure individual mental culture and, in interaction with environment, shape its behavioral expression. It will be recalled that the model of structured individual mental culture presented above comprises numbers of conceptually identified symbolic representations or nodes linked by a hierarchically ordered network of meaning-relations. The meaning of each node derives from the set of meaning-relations, linking it with other nodes or with higher level meaning-relationships in the structural hierarchy. Culturally significant action decisions depend not on the naming of nodes in the mental models summoned from memory to deal with specific situations, but on the meaning-relations between nodes. It it not the concept of duty *per se* which stipulates how one should act under certain circumstances, but how 'duty' relates to other mental representations. Such relations, which are culturally learned, are the basic elements in the semantic structure which I have called individual mental culture, for it is these relations which underlie all cultural behavior.

The fundamental units of individual mental culture, therefore, are the meaning-relations which link nodal representations. These are the cultural analogues of the genes[†].

The term 'meaning-relation' which I have identified as the component of mental structure which acts as the unit of replication in sociocultural evolution is clumsy and unsuitable as a designation for 'cultural genes'. Some other term needs to be used. The word 'meme' has been suggested, and it is one I would be happy to accept as referring to 'meaning-relations' as I have defined them were it not that definitions of the term are already so misleading (Dawkins, 1976; Mundinger, 1980). It is with some hesitation that I suggest yet another neologism. On balance, however, it does seem useful to do so. The term I suggest is 'menteme', a word which makes evident the location of these units of cultural replication in the human mind, and there alone; and which also states a certain family resemblance with other linguistic and semantic particulate entities such as phonemes and semenes. The difference between a menteme and a semene is that while a semene is the unit of meaning which attaches to a morpheme, the smallest structural semantic element in a language, a menteme is the smallest unit going to make up the structure of individual mental culture. A semene is arbitrary and symbolic; a menteme is neurally coded.

At any particular time an individual may scrutinize those mentemes going to make up the mental model held in consciousness. Mentemes may thus be subjectively identified through introspection. They may also be objectively identified through analysis of stated beliefs or observed behavior. In many cases it will be difficult to be sure that what has been identified as a menteme does constitute a minimal meaning-relationship. This is because, as with the transmission of genes, mentemes are often transmitted in interlocking combinations comprising complex concepts, ideas, or theories. Previous attempts to define a unit of cultural replication have failed because they have not carried the analysis of such combinations far enough. Since cultural transmission is often in the form of complex combinations of mentemes, the term 'meme' could be reserved for these. A meme, therefore, would be any interlocking group of mentemes regularly transmitted (or learned) as a simple combination[‡].

What has also made it difficult to identify mentemes is that, like genes, they have both polytypic and pleiotropic properties. Not only do combinations of various mentemes go to make up complex ideas, but a single menteme may play a role in the formulation of different ideas via the hierarchical relationship it has with other mentemes. What also makes the identification of mentemes difficult is that the same behavior may rest upon quite different menteme sets. Death rituals will include the sprinkling of ochre on the body if the meaning relationship between blood and ochre is one of magical identity. Only if this menteme set is communicated to and appropriated by individuals of the next generation will such rituals continue to be performed. But ancient beliefs may become attenuated over time. The sprinkling of ochre on the body may no longer be believed to give life in the next world. Yet the same ritual may continue to be performed simply because this was the way of the fathers. The meaning-relationship has now become one between ritual action and the authority of tradition, though the behavior remains the same.

The number of mentemes comprising any individual world view is determined by such factors as learning capacity, breadth of experience, value accorded to the accumulation of knowledge, flexibility, sophistication and complexity of mental structure, etc. As in

[†] On the primacy of relations, see Bateson (1972).

[‡] Since the phenotypic expression of combinations of mentemes would be easier to identify than the effects of individual mentemes, empirical research is likely to be concentrated on these first. But the same applies in biological evolution, for example in the case of continuous quantitative traits.

the case of genes a number of menteme alleles may occur as a single 'locus'. The earth may be thought to be a variety of different shapes in different cultures. Where mentemes are exclusively contradictory, they exist in allelic pairs. (Fairies either exist, or do not exist.) Unlike genes, however, variable forms of mentemes may be present at different points in the structure of different individual world views[†].

The human mind has the peculiar capacity of being able to accommodate opposing mentemes in different regions of mental space. Mentemes which conflict with those already firmly embedded in individual mental culture as the basis for behavior can be relegated to another part of mental space reserved for the beliefs of others where they will have no influence on behavior. The Flat Earth menteme relating the earth and flatness does not form part of the mental structure underlying the behavior of anyone who thinks the earth is round. It only forms part of the mental structure underlying behavior for a member of the Flat Earth Society. Those who believe the earth is round accommodate the relationship between the earth and flatness as the belief of an earlier age, or of a group of unaccountably odd people. As such it no longer influences behavior – except perhaps when meeting a member of the Flat Earth Society.

This brings me to the difficult relationship between mentemes, behavior, and material culture. Mentemes, I suggest, may be transmitted in a cultural context either individually or in a variety of combinations, through the processes of social learning[‡]. I have already pointed out the difference between representation in memory of perceptions of spatial relationships, an ability apparently shared with many animals, and the structuring of meaning-relations as individual mental culture, a capacity only present in a most rudimentary form, if at all, even in other primates. The purely spatial relationship between two trees in my memory of a country scene does not constitute a menteme. The ability mentally to represent spatial relationships evolved long before the capacity to form structures of meaning-relationships in man's phylogenetic history, and appears to be neurologically located in a different part of the brain (cf. O'Keefe & Nadel, 1979). A similar distinction can be drawn, I think, based on a similar difference between stages in phylogenetic evolution, between conditioned and conscious behavior in order to clarify the way in which mentemes influence behavior in general. Conditioned behavior is characteristic of the whole animal world: it evolved long before conscious behavior based on foresight and deliberation. But both forms of behavior are present in man, often so intertwined in a complex set of actions that it is almost impossible to disentangle them in order to discuss which actual behaviors have become automatic because conditioned, and which remain under conscious direction[§].

Instinctive behavior, such as ducking when something is thrown at one, is not dependent upon the cognitive hierarchy of meaning-relations. Nor are conditionally learned repetitive actions or habits. But the decision to perform a conditionally learned action

[†] This is why I do not think anything is to be gained by adopting Durham's term 'neme' for 'the alternative forms of a meme' (Durham, 1982: 317).

[‡] This transmission of mentemes is not a passive process. I would agree with Reynolds when he says that cultural transmission 'is an *effect* of observational learning and not a mechanism in itself' (his italics). Thus culture, as Reynolds maintains, is not a mode of transmission, but a process of interaction in which information encoded in a cultural artifact is rediscovered through observational learnings. Such learning entails 'the inferential creation of new conceptual linkages between actions and object concepts already in repertory based upon perceived novel relationships among examples of those concepts' [Reynolds (1981: 210); cf. Layzer's 'constructivist' approach to the formation of cognitive hypotheses, Layzer (1980: 225)]. Reynolds' demand for establishment of a systematic relationship between cultural content and individual psychology is precisely what my own hypothesis is designed to achieve.

[§] Cf. Berger and Luckmann's discussion of the relationship between habitualized and deliberate activity. 'The background of habitualized activity opens up a foreground for deliberation and innovation' (Berger & Luckmann, 1966: 51; also Johnson-Laird, 1983: 466–468).

may be dependent on menteme structure. And, of course, the decision to learn that action in the first place is so dependent. A child may learn the actions necessary to play a piece of music for a variety of reasons – to gain parental approval, for fear of punishment, in order to be allowed outside to play: but once learned, the mechanics of playing become conditioned. Musical notation is translated into the movement of fingers without the intervention of conscious thought. Whole sequences of such movements may be learned, so that their playing constitutes a single conditioned reflex as in the playing of a particular tune. But a decision to play is dependent on meaning-relations – to give pleasure to others, to express joy, to assuage personal grief. A tune *as it is being played* is part of both behavioral and material culture, even though the material effect is not lasting (unless recorded). Each note in a tune is not specified by a separate menteme: but the tune as a whole is linked through meaning- relations within individual world-view: the tune I first heard with X, the tune that Y likes, etc. The decision to play it on some occasion relates to these mentemes: but the playing of each note is not an action so dependent: it is instead a conditionally learned behavior.

Mentemes underlie all cultural behavior, not in the sense that every piece of behavior is under conscious control, but in the sense that every action which leads to the creation of culture requires a conscious decision taken in the context of individual world view to perform, even though the actual performance may be unconscious because the action was learned through a process of conditioning. Mentemes also underlie the decision to learn any culturally creative behavior in the first place, though those particular mentemes do not necessarily continue to influence decisions to repeat learned actions. Mentemes, like genes, depend for their expression on the environment. Social circumstances decide whether one menteme or another will find expression in behavior. X will play a piece of music he dislikes if his friend Y is present because X knows Y likes it and X wants to please Y. The menteme 'X dislikes tune A' which usually prevents X playing A is overruled by mentemes 'X likes Y' and 'Y likes tune A' *in the presence of Y*. The relation, therefore, between mentemes and behavior is directly analogous to that between genotype and phenotype: both depend upon environmental conditions.

To reiterate: the structure of mind no more *determines* behavior than genotype determines phenotype. Just as the expression of genes depends on environmental factors, so the behavior of any individual depends on the particular circumstances in which that person finds himself. Mental structure provides only a set of parameters defining possible reaction strategies, the choice of which depends on the particular situation. Behavior results from the interaction of mind and environment.

There is no space in this paper to examine the constraints which influence social selection, or how social selection relates to biological imperatives in human sociocultural evolution. That requires a lengthy paper of its own. Suffice it to say that the selection of mentemes proceeds by way of social learning during which those meaning-relationships perceived to be of value to the learner are appropriated into individual mental culture. The determination of what is valuable depends, of course, on both existing mental structures and perceived self interest.

The particulate nature of mentemes permits variants to occur (God does/does not exist; James is/is not kind; etc), and be differentially selected and retained in individual mental culture. Because complex representations are built up of combinations of mentemes, the loss or addition of one or two mentemes may only modify meaning slightly. By tracing the historical process of loss or addition of mentemes, it would be possible to explain slow changes of meaning of words and concepts†. Sociocultural innovation

† Such changes in meaning have been studied particularly by the French Annales school of historians of *mentalités*. Cf. the classic study by Lucien Febvre (1962).

can also derive from structural changes, new combinations of mentemes derived from personal contacts, or the vast pool of meaning-relationships available in materially encoded form (books, pictures, recordings, etc.). Clearly the processes of innovation and the differential selection of innovations in sociocultural evolution are complex ones which require far more careful study than they have yet received.

One final point I would like to make concerns the analogy which can be drawn between learning as the incorporation of mentemes in individual mental culture and the way in which scientific theories contribute to the evolution of knowledge. To begin with both mentemes and theories are hypothetical in the sense that both are interpretive guesses about the way the world is which are open to falsification in the light of subsequent empirical evidence†. This does not mean, of course, that both mentemes and theories are not held with total conviction. Nor does it mean that either mentemes or theories *will* be replaced the moment contrary evidence is available (Nisbett & Ross 1980; cf. Kuhn, 1962). Scientists attempt to shore up threatened theories with *ad hoc* additions just as assidiously as any individual protects his or her convictions with specious rationalizations. The strength of science lies in the fact that (a) its formal theory structure reflects the menteme structure underlying individual world view; and (b) as a social process requiring critical inputs from the community of scientific workers, it escapes many of the constraints (structural, but also affective in terms of emotional commitments to established mentemes) which often makes menteme replacement or modification difficult in individual world view. Contradictions between scientific theories are more easily located and critically eliminated than is the case with mentemes in individual mental culture, even in the most logical and critical mind, since recognition of the hypothetical nature of scientific theories has the effect that they are accepted by the scientific community with less emotional commitment than are, say, the mentemes comprising individual religious belief. My point is that the addition of theories to the structure of science contributes to the evolution of knowledge about the world in the same way that new mentemes added to the structure of mind can contribute to the development of understanding the world as encountered by each individual.

In conclusion, let me briefly summarize my argument. An analysis of what is covered by the term 'culture' permitted a distinction to be drawn between individual and communal culture and between three aspects of culture at the individual level – the mental, behavioral, and material. The locus of the cultural analogue of the gene, it was argued, must be at the individual mental level. A hypothetical model of the semantic structure of long-term memory was then proposed, extrapolated from the cognitivist conception of mind, and the conclusion reached that the cultural analogues of genes are the 'meaning-relations', or mentemes, which structure individual mental culture or world view. Mentemes were then shown to be the ultimate units of replication in cultural evolution, meeting the necessary requirements that they be particulate, variable, and open to cultural transmission and selective retention through inclusion in individual minds.

References

Alexander, R. D. (1979). In (N. A. Chagnon & W. Irons, Eds) *Evolutionary Biology and Human Social Behavior*. North Scituate, MA: Duxbury Press, pp. 59–78.

Alland, A. & McCay, B. (1973). In (J. J. Honigman, Ed.) *Handbook of Social and Cultural Anthropology*. Chicago: Rand McNally, pp. 143–178.

† On the relation between perception and hypotheses, see Medawar and Shelley (1980). On the evolution of knowledge, see Campbell (1960; 1974), Popper (1972) and Schrader (1980), among others.

Aronson, E. (1969). In (Leonard Berkowitz, Ed.) *Advances in Experimental Social Psychology*, vol. 4. New York: Academic Press.
Bajema, C. J. (1978). In (R. J. Meier, C. M. Otten & F. Abdel-Hameed, Eds) *Evolutionary Models and Studies in Human Diversity*. The Hague: Mouton pp. 47–61.
Baldwin, J. D. & Baldwin, J. I. (1981). *Beyond Sociobiology*. New York: Elsevier.
Bandura, A. (1977). *Social Learning Theory*. Englewod Cliffs, NJ: Prentice-Hall.
Barnett, H. G. (1953). *Innovation: The Basis of Cultural Change*. New York: McGraw-Hill.
Bateson, G. (1972). *Steps to an Ecology of Mind*. New York: Ballantine Books.
Berger, H., Jr. (1972). Outline of a general theory of culture change. *Clio* **2**, 49–63.
Berger, P. L. & Luckmann, T. (1966). *The Social Construction of Reality: A Treatise in the Sociology of Knowledge*. Garden City, NY: Doubleday.
Bock, W. J. (1978). Principles and methods of comparative analysis in sociobiology. In (A. L. Caplan, Ed.) *The Sociobiology Debate*. New York: Harper & Row. pp. 396–410.
Bohannan, P. (1973). Rethinking culture: A project for current anthropologists. *Cur. Anthrop.* **14**, 357–372.
Bonner, J. T. (1980). *The Evolution of Culture in Animals*. Princeton, NJ: Princeton University Press.
Boulding, K. E. (1978). *Ecodynamics: A New Theory of Societal Evolution*. Beverly Hills, CA: Sage.
Bronowski, J. (1977). *A Sense of the Future: Essays in Natural Philosophy*. Cambridge, MA: MIT Press.
Brown, R. (1973). *A First Language: The Early Stages*. Cambridge, MA: Harvard University Press.
Bruner, E. M. (1956). *Southwestern J. Anthropol.* **12**, 191–199.
Buckley, W. (1968). In (W. Buckley, Ed.) *Modern Systems Research for the Behavioral Scientist: a Sourcebook*. Chicago: Aldine, pp. 490–513.
Bulhof, I. N. (1980). *Wilhelm Dilthey: A Hermeneutic Approach to the Study of History and Culture*. The Hague: Martinus Nijhoff.
Burnham, P. (1971). In (C. Renfrew, Ed.) *The Explanation of Culture Change: Models In Prehistory*. London: Duckworth, pp. 93–102.
Campbell, D. T. (1960). Rentention in creative thought as in other knowledge *Psychol. Rev.* **67**, 380–400.
Campbell, D. T. (1965). In (H. R. Barringer, G. T. Blankton & R. W. Macks, Eds.) *Social Change in Developing Areas*. Cambridge, MA: Scheckman, pp. 19–49.
Campbell, D. T. (1974). Evolutionary epistemology. In (P. A. Schilpp, Ed.) *The Philosophy of Karl Popper*. La Salle, IL: Open Court.
Campbell, D. T. (1975). *Am. Psychol.* **30**, 1103–1126.
Campbell, M. (1978). *Methodol. Sci.* **11**, 129–145.
Cavalli-Sforza, L. L. (1971). In (F. R. Hodson, D. G. Kendall, & P. Tautu, Eds.) *Mathematics in Archaeological and Historical Sciences*. Edinburgh: Edinburgh University Press, pp. 535–541.
Cavalli-Sforza, L. L. & Feldman, M. W. (1981). *Cultural Transmission and Evolution: A Quantitative Approach*. Princeton, NJ: Princeton University Press.
Cloak, F. T. (1975). Is a cultural ethology possible? *Hum. Ecol.* **3**, 161–182.
Cloak, F. T. Jr. (1980). In (M. R. Key, Ed.) *The Relationship of Verbal and Nonverbal Communication*. The Hague: Mouton, pp. 327–348.
Collingwood, R. G. (1940). *An Essay on Metaphysics*. Oxford: Clarendon Press.
Daly, M. (1982). *Hum. Ecol.* **10**, 401–408.
Dawkins, R. (1976). *The Selfish Gene*. Oxford: Oxford University Press.
de Mey, Marc (1982). *The Cognitive Paradigm*. Dordrecht: Reidel.
Durham, W. H. (1976). The adaptive significance of cultural behavior. *Hum. Ecol.* **4**, 89–121.
Durham, W. H. (1979). In (N. A. Chagnon & W. Irons, Eds.) *Evolutionary Biology and Human Social Behavior*. North Scituate, MA: Duxbury Press, pp. 39–59.
Durham, W. H. (1982). *Hum. Ecol.* **10**; 289–323.
Emerson, A. (1956). In (Ray R. Grinker, Ed.) *Toward a Unified Theory of Behavior*. New York: Basic Books.
Febvre, L. (1962). *Le problème de l'incroyance au XVI siècle: la religion de Rabelais*. rev. ed. Paris: A Michel.
Flinn, M. V. & Alexander, R. D. (1982). *Hum. Ecol.* **10**; 383–399.

Geertz, C. (1973). *The Interpretation of Culture.* New York: Basic Books.
Gerard, R. W., Kluckholm, C. & Rapaport, A. (1956). *Behav. Sci.* **1**, 16–34.
Godfrey, L. R. & Cole, J. R. (1979). *Am. Anthrop.* **81**, 37–45.
Goffman, E. (1974). *Frame Analysis: An Essay on the Organization of Experience.* New York: Harper & Row.
Gombrich, E. H. (1982). *The Image and the Eye: further studies in the Psychology of Pictorial Representations.* Ithaca, NY: Cornell University Press.
Goodenough, W. H. (1957). In (P. Garvin, Ed.) *Report on the Seventh Annual Round Table Meeting on Linguistics and Language Study.* Washington, D.C: Georgetown University Monograph Series on Language and Linguistics, 9.
Goodenough, W. H. (1971). *Culture, Language and Society.* McCaleb Module in Anthropology. Reading, MA: Addison-Wesley.
Gould, S. J. (1980). *Paleobiology* **6**, 119–130.
Gregory, R. L. (1972). *Eye and Brain.* 2nd ed. London: Weidenfeld and Nicolson.
Grene, M. (1981) *Monist* **64**, 195–213.
Griffin, D. R. (Ed.) (1982). *Animal Mind – Human Mind.* Berlin: Springer-Verlag.
Habermas, J. (1979). *Communication and the Evolution of Society,* transl. by T. McCarthy. Boston: Beacon Press.
Harré, R. (1979). *Social Being: A Theory for Social Psychology.* Oxford: Basil Blackwell.
Harris, M. (1968). *The Rise of Anthropological Theory* London: Routledge & Kegan Paul.
Hayes-Roth, B. (1977). *Psychol. Rev.* **84**, 260–278.
Hill, J. (1971). A model for social evolution. *Sociol. Anal.* **1**, 61–76.
Hill, J. (1978). The origin of sociocultural evolution. *J. social biol. Struct.* **1**, 377–386.
Hoijer, H. (1954). In (Harry Hoijer, ed.) *Language in Culture.* Chicago: University of Chicago Press.
Hooker, C. A. (1975). *Philosophy Sci.* **42**, 152–179.
Huxley, J. S. (1956). Evolution, Cultural and Biological. In (W. L. Thomas, Jr. Ed.) *Curr. Anthrop.* Chicago: Chicago University Press, pp. 3–25.
Irons, W. (1979). Natural selection, adaptation and human social behavior. In (N. A. Chagnon & W. Irons, Eds) *Evolutionary Biology and Human Social Behavior.* North Scituate, MA: Duxbury Press, pp. 4–39.
Jackendoff, R. (1978). In (M. Halle, J. Bresnan, & G. A. Miller, Eds) *Linguistic Theory and Psychological Reality.* Cambridge, MA: The MIT Press, pp. 201–228.
Jensen, E. J. & Harré, R. (Eds.) (1981). *The Philosophy of Evolution.* Brighton: Harvester.
Johnson-Laird, P. N. (1983). *Mental Models.* Cambridge: Cambridge University Press.
Kaplan, S. (1973). In (R. M. Downs & D. Stea, Eds) *Image and Environment: Cognitive Mapping and Social Behavior.* Chicago: Aldine. pp. 63–78.
Kearney, M. (1975). *Ann. Rev. Anthrop.* **4**, 247–270.
Keesing, R. M. (1974). *Ann. Rev. Anthrop.* **3**, 73–87.
Ketner, K. L. (1972). An essay on the nature of world view. PhD. dissertation, University of California at Santa Barbara.
Kroeber, A. & Kluckholm, C. (1952). *Pap. Peabody Mus.* **47**(1). Cambridge, MA: Harvard University Press.
Kuhn, T. S. (1962). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.
Layzer, D. (1980). In (A. Montagu, Ed.) *Sociobiology Examined.* New York: Oxford University Press, pp. 220–253.
Lieblich, I. & Arbib, M. A. (1982). *Behavl Brain Sci.* **5**, 627–659.
Lumsden, C. J. & Wilson, E. O. (1981). *Genes, Mind, and Culture: The Coevolutionary Process.* Cambridge, MA: Harvard University Press.
Lumsden, C. J. & Wilson, E. O. (1982). *Behavl Brain Sci.* **5**: 1–37.
Masters, R. D. (1970). *Semiotica* **2**, 295–320.
McNeill, D. (1979). *The Conceptual Basis of Language* Hillsdale, NJ: Lawrence Erlbaum Associates.
Medawar, P. (1975). In (Saul Bellow *et al.*, Eds) *Technology and the Frontiers of Knowledge.* Garden City, NY: Doubleday. pp. 101–109.
Medawar, P. B. (1981). *N.Y. Rev. Books.* 16 July 1981, pp. 45–48. [Review of Lumsden & Wilson, 1981.]
Medawar, P. & Shelley, J. H. (1980). *Structure in Science and Art.* Amsterdam: Excerpta Medica.
Minsky, M. (1975). In (P. H. Winston, Ed.) *The Psychology of Computer Vision.* New York: McGraw-Hill, 1975.

Mundinger, P. C. (1980). *Ethol. Sociobiol.* **1**, 183–223.
Murdock, G. P. (1960). In (H. L. Shapiro Ed.) *Man, Culture, and Society*. New York: Oxford University Press, pp. 247–260.
Nisbett, R. E. & Ross, L. (1980). *Human Interference: Strategies and Shortcomings of Social Judgment*. Englewood Cliffs, NJ: Prentice Hall.
O'Keefe, J. & Nadel, L. (1979). *Behavl. Brain Sci.* **2**, 487–494, 520–533.
Osgood, C. E. (1960). *Publ. Opin. Q.* **24**, 341–365.
Parsons, T. (1966). *Societies: Evolutionary and Comparative Perspectives*. Englewood Cliffs, NJ: Prentice-Hall.
Pepper, S. (1942). *World Hypotheses: A Study in Evidence*. Berkeley: University of California Press.
Piaget, J. (1977). *The Essential Piaget*. (H. E. Guber & J. J. Vonèche, Eds.) London: Routledge & Kegan Paul.
Plotkin, H. C. & Odling-Smee, F. J. (1981). *Behavl. Brain Sci.* **4**, 225–268.
Popper, K. R. (1961). *The Poverty of Historicism*. 2nd ed. London: Routledge & Kegan Paul.
Popper, K. R. (1972). *Objective Knowledge: An Evolutionary Approach*. Oxford: Clarendon Press.
Pulliam, H. R. & Dunford, C. (1980). *Programmed to Learn: An Essay on the Evolution of Culture*. New York: Columbia University Press.
Reidl, R. (1977). A systems-analytical approach to macroevolutionary phenomena. *Q. Rev. Biol.* **52**, 351–369.
Reynolds, P. C. (1981). *On the Evolution of Human Behavior: The Argument from Animals to Man*. Berkeley, CA: University of California Press.
Richerson, P. J. & Boyd, R. (1978). *J. social biol. Struct.* **1**, 127–154.
Rogers, E. M. (1976). In (W. Schramm & D. Learner, Eds.) *Communication and Change: The Last Ten Years – And the Next*. Honolulu: University Press of Hawaii, pp. 204–222.
Rosenthal, T. L. & Zimmerman, B. J. (1978). *Social Learning and Cognition*. New York: Academic Press.
Ruse, M. (1982). *Darwinism Defended: A Guide to the Evolution Controversies*. London: Addison-Wesley.
Ruyle, E. E. (1973). *Hum. Ecol.* **1**, 201–215.
Sahlins, M. D. & Service, E. R. (Eds.) (1960). *Evolution and Culture*. Ann Arbor: University of Michigan Press.
Schneider, L. (1973). In (L. Schneider & C. M. Bonjean, Eds.) *The Idea of Culture in the Social Sciences*. Cambridge: Cambridge University Press.
Schon, D. A. (1963). *Invention and the Evolution of Ideas*. London: Tavistock.
Schrader, D. (1980). *Rev. Metaphys.* **34**, 273–296.
Simon, H. A. (1979). *Ann. Rev. Psychol.* **30**, 363–396.
Smith, E. E. (1978). In (W. K. Estes, Ed.) *Handbook of Learning and Cognitive Processes*, vol. 6. Hillsdale, NJ: Erlbaum, pp. 1–56.
Spencer, H. (1972). *On Social Evolution: Selected Writings*. Chicago: University of Chicago Press.
Sperry, R. W. (1969). *Psychol. Rev.* **76**, 532–536.
Steward, J. H. (1960). In (S. Tax, Ed.) *Evolution After Darwin*, vol. 2. Chicago: University of Chicago Press.
Wickelgren, W. A. (1981). *Am. Rev. Psychol.* **32**, 21–52.