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Chapter 18

Getting an Idea of Culture

If we want to develop something called *Cutural* Grammar Systems, it is necessary, of course, to start by making clear what culture is. To do so, it would be helpful to define culture, to establish which its properties are and what kind of units can be considered as basic of it.

But, in the introduction we have emphasized the idea that human evolution is the product of genes and culture, and that our Cultural Grammar System intends to put in evidence this relationship between biology and culture. So, it is not enough to present just what culture is. It is important to put in relation cultural and biological evolution. The relationship between genes and culture is not a new issue in the scientific community. It has originated several debates in very different fields and constitutes one of the major challenges that behavioral sciences face nowadays. So, we retain important to mention some works that have explicitly referred to the relationship of these two major information systems, before entering in the presentation of our *grammatical* model of cultural evolution.

18.1 What is Culture?

18.1.1 Definitions

If there is something really difficult, this is, sure, to define 'culture.' Since the definition of culture by E.B Tylor, in his book *Primitive Culture* (1871), as *'that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society,'* many are the definitions we can find out in the literature. Kroeber and Kluchholm have made a comprehensive survey of a great number of remarkable definitions of the term culture coined before 1950, collecting 164 definitions of culture proposed by historians and social scientists. Those definitions (cited by [Vermeersch, 1977]) are divided into three categories:

1. enumerative definitions,
2. definitions by criterion,
3. definitions using a combination of both methods.

The first type -the so-called enumerative definitions- presents an obvious problem: they are always inevitably incomplete, and consequently, inadequate. Those definitions indicate sets of cultural objects. They refer to mental states and processes such as 'knowledge,' 'ideas,' 'beliefs,' 'attitudes,' etc.; or to patterns of behavior using notions such as 'habits,' 'customs;' some of them speak about methods of communication or skills; others allude to the products of human activity; and even there are some which include everything related to the concept of Institution. Anyway, independently of which kind of components are stressed in these definitions, the obvious fact is that a complete enumerative definition of culture is almost impossible to get.

In what refers to the second type of definitions -definitions by criterion- there are some that emphasize the fact that cultural objects belong to more

than one individual at the same time and to individuals of successive generations, they stress, therefore, the social and historical dimension; others point out some theoretical characteristics as can be the idea of adaptation - defining cultural objects as ways of adjusting, as adaptive useful behavior- or the dynamic aspects of culture; and we can find, also, those definitions that center themselves of the creation and the survival of cultural objects emphasizing the idea of man-made and artificiality of cultural objects and pointing out the independency of genetic inheritance in the transmission of culture.

And finally, the third type of definitions is just a combination of those two other kinds, this is, definitions that combine enumeration and criterion.

Many other classifications of culture definitions have been established. In 1974, for example, Keesing (cited by [Boyd & Richerson, 1985, p. 33]) argues that conceptions of culture fall into four distinct categories which differ in several fundamental ways. Members of one group define culture in terms of observable, socially transmitted patterns of behavior. The other three categories of theories define culture exclusively in terms of ideas.

It seems that there are infinite many classifications of types of definitions about culture. But, what is culture? It seems that it is no so trivial to define it. Every definition has advantages and disadvantages, so, how to decide what is the 'good' definition? [Vermeersch, 1977], citing Anderson and Moore, proposed several 'conditions of adequacy' that must be respected by every definition in order to be acceptable as a basic concept of culture:

1. we must be able to speak of *cultural change*: cultural objects must be of such a kind that they can be said to change in the course of time;

2. some cultural phenomena do not change in the course of time, so we should be able to discuss the *persistence* of cultural objects;

3. cultural objects can move from one society to another, so it must be possible to deal with *cultural diffusion*;

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4. since cultural objects may be created in a particular society or may disappear and be rediscovered, we should be able to study *cultural innovation, disappearance, and reappearance.*

Anyway, even following these guidelines, it is not trivial to give a complete and perfect definition of culture. Therefore the only think we can do, by now, is to collect different definitions proposed by authors included in our bibliography, organizing them in our *own* classification and expecting to have after that survey, if not more, some blurred idea of what culture is.

Our classification of culture definitions include the following three different types:

1. culture as a *transmission system*,
2. culture as *standards of behavior*,
3. culture as *shared ideas.*

Within the first group -culture as a *transmission system*- we find definitions as

> *'By culture we mean the transmission from one generation to the next, via teaching and imitation, of knowledge, values, and other factors that influence behavior.'* [Boyd & Richerson, 1985, p. 2].

given by Boyd and Richerson.

In the same line can be seen what -according to [Durham, 1991]- is the currently view of Anthropology, which regards cultures as systems of symbolically encoded conceptual phenomena that are socially and historically transmitted within and between populations.

And also Hutchins and Hazlehurst view of culture as a process can be included in this type of definitions. The authors assert that

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> *'Culture is not a thing or any collection of things, it is a process. In the human sphere, myths, tools, understandings, beliefs, practices, artifacts, architectures, classification schemes, etc. alone or in combination do not in themselves constitute culture. Each of these structures, whether internal or external, is a residue of the cultural process. The residues are, of course, indispensable to the process, but taking them to be culture itself diverts our attention from the nature of the cultural process.'*
> [Hutchins & Hazlehurst, 1992, p. 692].

Many definitions fall under the second heading -culture as *standards of behavior.*

According to Ward Goodenough, the term culture must be reserved for *'what is learned, for the things one needs to know in order to meet the standards of others.'* [Goodenough, 1981, p. 50]. Culture, according to this author, can be reduced to a set of standards:

> *'Stantards for deciding what is, standards for deciding what can be, standards for deciding how one feels about it, standards for deciding what to do about it, and standards for deciding how to go about doing it.'* [Goodenough, 1981, p. 62].

> *'The expectations one has of one's fellows may be regarded as a set of standards for perceiving, believing, evaluating, communicating, acting. These standards constitute the culture that one attributes to one's fellows; and it is in this sense of standards that I use the term culture here.'* [Goodenough, 1970, p. 99].

So, a society's culture is defined as *'whatever it is one has to know or believe in order to operate in a manner acceptable to its members, and do so*

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in any role that they accept for any one of themselves.' [Goodenough, 1981, p. 109].

In the same line are Cavalli-Sforza and Feldman who, following the Webster's Dictionary, define culture as:

> *'...the total patttern of human behavior and its products embodied in thought, speech, action, and dependent upon man's capacity for learning and transmitting knowledge to succeeding generations through the use of tools, language, and systems of abstract thought.'* [Cavalli-Sforza & Feldman, 1981, p. 3].

For Marvin Harris culture can be regarded as:

> *'...patterns of behavior, thought and feeling that are acquired or influenced through learning and that are characteristic of groups of people rather than of individuals.'* (cited by [Boyd & Richerson, 1985, p. 33]).

Also in Reynolds we find the idea of pattern of behavior, when he understands culture as that thing that *'tells the members of each society how to live their lives.'* [Reynolds, 1984, p. 76].

And a guide for behavior is culture, as well, in Freilich's view:

> *'By culture we mean all those historically created designs for living, explicit and implicit, rational and irrational, and non-rational, which exist at any given time as potential guides for the behavior of men.'* [Freilich, 1977, p. 89].

But this author points out a very imporant thing: Culture must not be confused with behavior, nor with any of the material consequences of systematic

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action. *Culture is information, behavior is action.* And this is so, because culture is nothing else that a set of 'potential guides' which may or may not be followed. In every case, all kinds of environmental factors enter, impeding a one-to-one relationship between culture and behavior.

According to Morris Freilich, thus, culture can be viewed as a *guidance system.* This author understands a guidance system as a bit of information that makes one type of behavior more probable than another. People who share space, share a number of guides. These guides can be *natural* as for instance physiological drives, climate, etc. or they can be *standards,* this is, guides that are man-made and develop as a by-product of social interaction. Obviously, culture belongs to the second type of guidance systems, the so-called standards.

Patterns of behavior is culture, as well, for Ortner, Donald and Stonier. The first one defines culture as *'the traits, complexes and patterns of relationships between and among people that characterize a society.'* [Ortner, 1983, p. 136]. For the second, culture is nothing else than *'shared patterns of acquired behavior characteristic of a species.'* [Donald, 1991, p. 9]. And the last one speaks of culture in terms of *'society's communal database upon which it draws to define belief systems and accepted modes of behaviors patterns.'* [Stonier, 1992].

In the third type of our classification -culture as *shared ideas*- can be placed LeVine's definition of culture as

> *'A shared organization of ideas that includes the intellectual, moral, and aesthetic standards prevalent in a community and the meanings of communicative actions.'* [LeVine, 1984, p. 6].

Finally, to finish this review of culture definitions, it is worth to refer to Bargatzky's definition of a cultural system as nothing else that *'a struc-*

ture,' but *hierarchical structure* [Bargatzky, 1984, p. 402]. And D' Andrade conception of culture as consisting of

> *'Learned systems of meaning, communicated by means of natural language and other symbol systems. Through these systems of meaning, groups of people adapt to their environment and structure interpersonal activities.'* [D'Andrade, 1984, p. 116].

With the definitions of culture pointed out above we should start to have a more or less approximate idea of what culture is. But, just in the case those definitions would not be enough, let see some of the properties that have been attributed to culture.

18.1.2 Properties

Following [Durham, 1991], we can point to five properties that somehow define culture:

1. *Systemic Organization.* Culture takes the form of a 'system of knowledge' within a population. The structure of this system of knowledge is both:

   (a) *hierarchical*, in the sense that some information is more basic and of a higher order than the rest, and

   (b) *coherent*, this is, component beliefs are linked together and embedded within the whole.

2. *Social transmission.* Culture is transmitted *socially* within or between populations. If we are to qualify a given unit of information as cultural, it must be learned from other individuals, not transmitted genetically or acquired from isolation individual experience, as in trial-and-error learning.

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3. *Conceptual Reality.* Culture consists of shared ideational phenomena (values, ideas, beliefs, and the like) in the minds of human beings. It refers to a body of information that is both:

   (a) *public*, this is, socially shared, and

   (b) *prescriptive*, in the sense of actually or potentially guiding behavior.

4. *Symbolic Encoding.* According to Durham, culture is strongly dependent on symbolic encoding.

5. *Social History.* The shared ideas, values, and beliefs of a culture do not emerge fully developed as if they were put in their place by a single and inmmutable act of creation, they have all been handed down from prior forms.

With the above properties attributable to culture we should be closer to a clear idea of what can be understood by 'culture,' but let us say a little bit more in order to make clearer that notion.

18.1.3 Units

Many are the notions that have been proposed in the literature as possible candidates for accounting as basic units of culture. 'Idea,' 'belief,' 'thought,' 'role,' 'value,' 'principle,' 'premise,' 'postulate,' 'instruction,' 'concept' are some examples. But, how must be an useful unit of culture? According to [Durham, 1991], any good notion for accounting as unit of culture should attend the following conditions:

- it should consist of information that actually or potentially guides behavior;

- it should take into account highly variable kinds, quantities, and ways of organizing information, that is, it should accomodate with variable amount of hierarchy and integration;
- and finally, it should demarcate bodies of information that are, in fact, differentially transmitted as coherent, functional units.

Respecting these three properties we find few proposals. According to Durham, just two of the cultural units that have been proposed can be accepted: *'symbol,'* when defined to be any vehicle for the transmission of socially meaningful information; and *'meme,'* when defined by Richard Dawkins to be the unit of information that *'propagate itself in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called Imitation.'* [Dawkins, 1976, p. 192].

18.2 Models of Gene-Culture Interaction

We have said, in the introduction to this chapter, that the relationship between genes and culture constitutes one of the major challenges that behavioral sciences face in our days. In general, there are agreement about the fact that human beings are the product of genes and culture, and that we cannot understand man without taking into consideration both elements and the interrelationship betweem them. Starting from this truism, several models have been presented in which we can see different levels of interrelation between biological and cultural facts and where scholars give causal priority to one element or another.

In [Durham, 1991], it is proposed a three-way classification of models of gene-culture relations. This classification emphasizes two questions:

1. Is culture a second inheritance system?

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2. What are the best units to use in the study of cultural transmission?

Three different kinds of answer to those two questions are found. Those different answers bring Durham to establish the following classification of gene-culture models:

- *Models without dual inheritance.* This type of models pays heed to the concept of culture but without distinguishing it as a second inheritance system. They do not include an evolutionary theory of cultural change and they do not recognize units with evolutionary fitness in the cultural systems. Culture is conceptualized as part of the phenotype.

- *Models with dual inheritance and trait units.* In these models, culture is viewed as a second, nongenetic inheritance system whose units are defined culturally heritable aspects. These units are recognized as having their own measure of fitness within the cultural system.

- *Models with dual inheritance and ideational units.* In these models the answer to the first question is yes, but the answer to the second question is not in terms of traits or other phenotypic units. Rather culture is conceptualized in terms of ideational units. Culture is a separate 'track' of informational inheritance, but one with a number of features that are more or less analogous to the features of the genetic 'track.'

Let see some of those models in which culture is considered as an second inheritance system different from biology but interrelated with it.

[Durham, 1991], for example, outlines a general theory for relating genetic and cultural evolution in human population called *Coevolution.* The theory centers itself on evolutionary change in human cultural systems and on its relationship to dynamics of genetic evolution. The theory is called *Coevolution*, precisely, to emphasize that genetic and cultural selection have harmonious

and parallel influences on guiding evolution of human diversity. The author presents the general conceptual structure of his theory in the following terms:

> *'...the genes, G_i, and culture, C_i, of a hypothetical human population in generation i are represented as distinct though interacting systems or 'tracks' of inheritance. Both tracks are subject to sequential transformation under the influence of the environment, E, which includes the existing social system S_i. Guiding the transformation of culture are the sets of laws T_a and T_b, representing the changes introduced by learning and imitation and those introduced by teaching and dissemination. In contrast to the genetic laws, these laws of cultural transformation are represented by multiple arrows in each generation in order to emphasize that cultural instructions to the phenotypes can be 'inherit' continously throughout life and that they can also change during people's lifetimes.'* [Durham, 1991, p. 187].

As it follows from the above quotation, the structure emphasizes the fact that culture is a parallel transmission system whose influence on phenotypes is symmetric with respect to that of genes. Phenotypes are, thus, subject to Coevolutionary influences of genes and culture. This 'co-' emphasizes that genes and culture constitute symmetrical inputs to phenotypes and that their influences are expected to show certain 'harmony' on average.

Another dual-inheritance model is found in [Boyd & Richerson, 1985]. Here, authors propose a new theory to construct simple mathematical models for cultural transmission. These models of cultural transmission are linked to models of genetic evolution, in order to determine the circumstances under which natural selection might favor the models of cultural transmission. In order to emphasize the fact that determinants of human behavior are transmitted via two structurally different inheritance systems, Boyd and Richerson call their model *Dual-Inheritance Theory.*

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Also in [Lopreato, 1984] we find an intimate interplay of biology and culture. The author stresses the idea that *'instinct and learning, nature and nurture, the innate and the learned -in short, biology and culture- are inextricably interwoven together.'* [Lopreato, 1984, p. 74].

In [Lumsden & Wilson, 1985], authors stress the relationship between genetic and cultural evolution by presenting what they call the *gene-culture transmission model.* After defining the basic unit of culture to be a 'culturgen,' Lumsden and Wilson differentiate three conceivable classes of culturgen transmission:

1. 'pure genetic transmission,'
2. 'pure cultural transmission,'
3. 'gene-culture transmission.'

According to the authors the third one, gene-culture transmission appears to be the most likely mode of inheritance for all categories of culturgens. This model points clearly to the need for a theory of cultural change that explicitly integrates the influences of gene, environment and culture on the differential transmission of cultural form.

Also the theory presented by Forrester in his *World Dymanics* could be seen as a way of making clear that the behavior of the world, and therefore of human beings, must be explained as an interaction of biology and culture. Roughly speaking, [Forrester, 1973] presents a theory of behavior and interaction in which some forces and their interrelationship form a dynamic model showing how the behavior of the world results from mutual interplay between its demographic, industrial and agricultural subsystems. A 'world system' is defined as being composed by man, his social systems, his technology, and the natural environment. According to the author these elements interact to produce growth, change and stress. Forrester presents rules describing how

each part of the system operates in response to pressures and influences from other parts of the system. Obviously, by allowing the elements of the model to interact we can observe the dynamic nature of the system.

In opposition to previous authors, [Flinn & Alexander, 1982] argue that the dichotomy of cultural versus biological evolution tacitly or explicitly accepted by proponents of what is usually called the coevolutionary perspective is *inappropriate and misleading.* They think that culture-biology dichotomy derives from misunderstanding and misstatements of certain aspects of biological theory. Flinn and Alexander defend the idea that culture can be regarded as an aspect of the environment into which each human is born and must succeed or fail. They think that cultural traits are, in general, vehicles of genic survival.

We have already seen in this introduction what can be understood by 'culture,' which its properties are and which kind of units can be considered as its basic constituents. We have also briefly presented some models which make clear the importance of considering culture as a second inheritance system as well as the necessity of establishing a relationship between culture and biology in order to explain human behavior and evolution. So, with this base, we are ready to start with the presentation of our Cultural Grammar Systems.

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Chapter 19

Our Proposal: Cultural Grammar Systems

In the two previous chapters we have briefly presented Cultural Algorithms, pointing out the importance that such model has exerted in our hypothesis of the possible applicability of Grammar Systems Theory to description of cultural change. We have intended to get an approximately idea of culture by defining it, by identifying its units and by individuating some of its properties. We have also reviewed some modes of gene-culture interaction in order to see how different authors have treated the interrelation among those two inheritance systems. Now it is time to introduce our formal framework.

In this chapter we will present Cultural Grammar Systems. We will carry out such presentation in two steps:

1. first, we will build up the model step by step, in an informal way, justifying at every stage why we have considered some specific elements and relationships and not others;

2. second, we will formalize the framework. Such formalization will be carried out, again, step by step, in order to make clear why we have

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opted for the formal definitions we have included in our framework.

We will close the chapter by bringing together the picture we have built in the first part of our task, and formal definitions we have obtained in the second part of it. We will offer, as well, an example of Cultural Grammar Systems.

19.1 From Eco-Grammar to Cultural Grammar

19.1.1 Culture & Genetics: Separate Environments

> *'Genes and culture constitute two distinct but interacting systems of information inheritance within human populations.'*
> [Durham, 1991, p. 419].

Since the beginning of this part of our dissertation, we have emphasized that man is biology and culture, that we cannot understand the behavior of human beings but as the interaction of genes and culture. We have referred that several authors from many fields have pointed out the necessity to differentiate culture as a second inheritance system different from genetic-inheritance system.

Many are the reasons that have been provided for considering culture as different from genes. In Durham words

> *'Culture deserves recognition as a distinct inheritance system by virtue of its conceptual reality and social transmission. Because of these features, culture provides information guides to behavior that are shared within populations, but are not passed through*

> *DNA. The result is an effective 'second channel' of information transfer within human populations, a second inheritance system.'* [Durham, 1991, p. 159].

That genetic and cultural inheritance systems are two different things and not the same is amply demonstrated by the following facts adduced by several researchers working in cultural evolution (cfr. [Durham, 1991, Boyd & Richerson, 1985]):

- genes and culture each contains information within very different codes: DNA versus Memes (or whatever unit of culture we consider);
- the information is stored and processed in different, highly specialized structures: cell nuclei versus the brain;
- cultural and genetic information is transmitted through very different mechanisms: sexual versus social relations;
- while biological innovations are perpetuated by reproduction, which is a one-way street, this is, offspring inherit from parents but cannot reciprocate; cultural innovations -being transmitted by learning- override the barriers of kinship, age, sex, generation, race, language and even physical proximity. Using the typology of Cavalli-Sforza and Feldman, we can say that genetic transmission is strictly 'vertical' (from parents to offspring), while cultural transmission is 'horizontal' (between any two (usually unrelated) individuals of the same generation) or 'oblique' (from a member of a given generation to a member of the next (or later) generation who is not his or her child or direct descendant);
- cultural transmission occurs after birth, so individuals are at least partly developed when they are enculturated, whereas genetic transmission takes place before birth. Moreover, culture is acquired sequentially over

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time, rather than -as occurs with genetic transmission- all at once at a single moment in the life cycle;

- cultural information acquired by an individual may be affected by the events of his life, and, if so, the changes will be transmitted to an individual's cultural offspring. In contrast, the genetic information transmitted by an individual is unaffected by the events of his life, an adaptive genetic evolution can only occur by the differential survival or reproduction of variant individuals in the population. Some authors will say that cultural transmission is Lamarckian while genetic transmission is Darwinian[1].

Summing up, we can say that culture is different from genes both:

1. in *content*, and
2. in *mechanism*.

In terms of *content*, culture consists of learned information that is received and processed within the brains and nervous systems of it carriers. This socially transmitted information is not incorporated into the biochemical code of genetic inheritance system. Therefore, those two different forms of

[1]Darwinian evolution is a process of random mutation and natural selection. Under that process, small changes take place during the process of reproduction, producing random variations in the offspring. If these changes are not favorable then the offspring may die out. If these changes are favorable, however, then the offspring reproduce more frequently, passing these changes on so that they propagate. Only genetic information is transmitted. An alternate mechanism of biological evolution was postulated by Lamarck. He believed in the transmission of acquired characteristics to subsequent generations. We now know that this is not true for biological organisms. However, there is an important context in which it is true: evolution of culture. In contrast to biological evolution, in social evolution acquired characteristics are passed on to subsequent generations. Cultural evolution is essentially a Lamarckian process rather than Darwinian.

information -one in brains, the other in genes- remain biochemically distinct throughout the lifetime of every individual. They may both act as guides to behavior, nevertheless, they coexist as distinct and separate forms of information.

In terms of mechanisms, the ones used to transmit cultural information differ from those of genetic transmission:

- in *tempo*. Cultural transmission is much more rapid than the process of genetic transmission;
- in *mode*. The mode of transmission in culture is often conveyed 'horizontally' (among peers) and 'obliquely' (from nonparental elders), in contrast with the 'vertical' transmission of genes;
- and in *ratio*. In addition to the one-to-one ratio of the genetic transmission, cultural transmission can also be many-to-one or one-to-many.

But of course, not everything is different in biological and cultural systems. The two inheritance systems, as we have seen, consist in different units and transmit the information in very different ways, however they present important similarities, as has been pointed up by several authors (cfr. [Boyd & Richerson, 1985]):

- both constitute systems to organize information;
- both systems, separately or in combination, are capable of causing heritable change in the nature of phenotypes;
- both systems are capable of evolutionary transformation through space and time;
- evolutionary change in both systems exhibits the properties of:

  - *multiplicity*, -that is, the existence of multiple causal forces of transformation,
  - and *selectivity*, or the propensity for non-random differential transmission of variants;

- neither system exerts its influence on a way that could be described as deterministic. In both cases environment and chance effects are involved;

- in both cases we can say that a stable structure is transmitted. The genotype of an individual is for the most part determined by what it has inherited from its parents. Even though mutation can act to change an individual's genotype spontaneously, the rate of change is very slow. Also in the case of culture, the evidence from social learning theory suggests that some cultural traits are similarly transmissible and reasonably stable;

- offspring derives its genotype by 'sampling' two individuals from the population, its mother and father. Similarly, some studies indicate that humans sample only a small number of individuals (although very often more than two) during the acquisition of any particular cultural trait.

Some of those similarities have led several authors to suggest that an analogy between cultural and genetic evolution can be fruitful in order to get useful explanations (cfr. [Boyd & Richerson, 1985, Cavalli-Sforza & Feldman, 1981]). Cavalli-Sforza and Feldman, for example, assert that forces of mutation, selection, migration, and drift which are central to the theory of biological evolution under genetic transmission, have analogues in the specific-trait approach to cultural evolution.

Summing up, differences between genes and culture support the idea of considering culture and biology as a two different inheritance systems, and

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similarities suggest that the two systems have several things in common. Anyway, if something is important to be stressed is that even though there are several differences between genes and culture -as well as many analogies- these two inheritance systems are interdependent: we cannot understand cultural evolution without knowledge of biological evolution, but, on the other hand, we cannot forget that biological evolution is *'only one of many possible kinds of evolution.'* [Dawkins, 1976, p. 193]. So, we need biology and culture. This idea lays the foundation stone of our Cultural Grammar Systems model that, of course, will reflect these two inheritance-systems by having two different environments:

1. biological environment or genetic system[2],
2. cultural environments.

as shown in figure 19.1.

As it can be seen in figure 19.1, we have placed in our model *one* biological environment and *several* cultural environments. The reason that can be adduced for having just one biological environment and several cultural ones is, of course, the necessary abstraction in a formal model as the one we are trying to construct. But this abstraction is based in some real circumstances. If we look at what happens in the real world, we will see that in general cultural variation is expected to be potentially enormous compared to biological variation. Comparing biological and cultural variation among populations it seems, at first sight, that cultural variation is rather fine-grained so that even the first racial subdivision would leave us with groups that are culturally very heterogenous. So, attending to this real circumstance we have deemed it wise to consider just one biological system and several cultural environments, in order to fit somehow to this bigger cultural variation found in the world.

[2]We will use 'genetic system' and 'biological environment' indifferently, with the same meaning, along this part of the dissertation.

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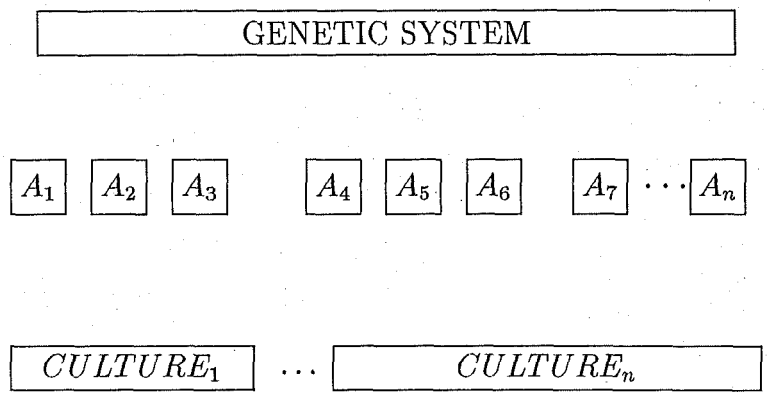

Figure 19.1: Cultures and Genetic System: Separate Environments

19.1.2 ... And Where is the Environment?

> *'One cannot hope to fully appreciate and understand the nature of human evolution without deliberatively seeking the kinds of relationships between man's physical, biological and social environments.'* [Beals & Kelso, 1975, p. 566].

Till now we have talked about biological and cultural systems. But if one seeks to understand and explain human behavior it is necessary to introduce a third element: the *environment.* We will obtain, then, figure 19.2.

As [Gabora, 1997] points out, the pattern in the structure and dynamics of information we encounter in everyday world can be traced to three causal principles: the ones mentioned till now -*cultural and biological evolution*- plus the one related to the environment - *physical constraints.* But Gabora is not the only one in pointing the importance of considering these three elements. In [Reynolds, 1984], it is also recognized three types of evolution - physical, organic and cultural. Once more, [Cavalli-Sforza & Feldman, 1981]

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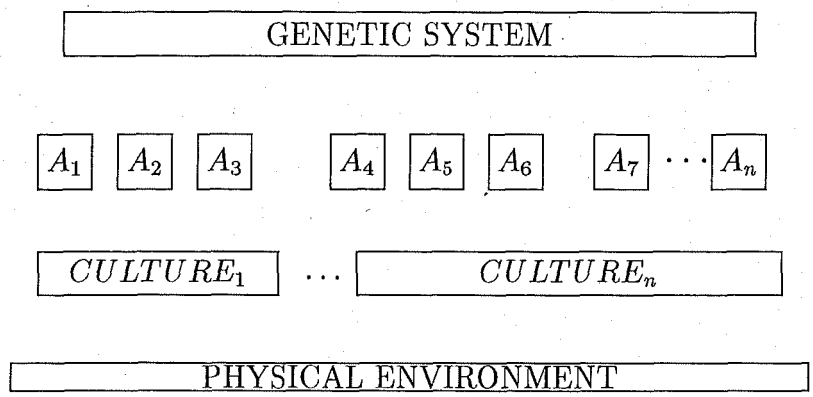

Figure 19.2: Adding the Environment

make reference to the same three types of adaptation - cultural, physiological, and genetic. And, of course, also for [Durham, 1991], the trichotomy -genes, culture, environment- makes more sense than a simple dichotomy.

There is a great interaction, of course, between physical, biological and cultural environments. This interaction, together with the fact that the three components can have similar effects on the phenotypes, makes sometimes very difficult to distinguish the effects of genetic, cultural and environmental variation on human behavior. Anyway, we must be able of making a clear distinction of the three elements, without forgetting, of course, their interaction in human behavior.

As part of the biological environment we have placed genes as basic units; 'memes' or the like are considered the units of culture. Now, what is inside the 'environment'? As part of the environment authors have seen the local climate, the kinds of food items available, local predators, etc. But independently of what is inside the environment, it is so important to emphasize its 'external' position. As is pointed out by Boyd and Richerson, the '*envi-*

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ronment should be restricted to those processes in the physical and biological realm that affect the population of interest but that are somehow external to the population itself' [Boyd & Richerson, 1985, p. 5]. This idea of 'externality' is stressed very much by pointing out that, for example, environmental conditions are not strongly affected by evolutionary changes in the population; so, we can say that environmental factors are somehow 'exogenous' to the evolving population.

But, in spite of that 'external' or 'exogenous' position of the environment, and even though man is constrained by the environment where he lives and is obligated to adapt to the conditions of the environmental system, it is important to emphasize -following [Bargatzky, 1984]- that man is not just a 'slave' of its environment, but he actively modifies it. Therefore, when we think of man, we cannot see him as a 'passive' organism that adapts himself to the features of the environment, but we have to see him as an 'active' organism, able to modify *somehow* his environment.

So, as it is reflected in figure 19.2, we end up this section with one more element in our Cultural Grammar Systems model, we do not have just cultural and biological environments, but also a *physical environment.*

19.1.3 Further Divisions: Subcultures

Up to now, in our model we have a set of *agents* that belong to a specific *cultural environment* and that are constrained by their *genetic* properties as well as by the *physical environment* were they are living and developing their activities. But, to be as close as possible to what happens in the real world, I think it is convenient to introduce an intermediate level between culture and individuals: *subcultures.*

Several authors have pointed out the necessity of this further division. For example, in [Cavalli-Sforza & Feldman, 1981], the authors speak about

the stratification of the whole population into subgroups within which a high level of communication occurs, but among which a different, reduced level exists. According to Cavalli-Sforza and Feldman these different strata can represent several things: socioeconomic classes, religions, castes, dialects, etc. The criteria by which subgroups are identified as strata usually depend on variables such as the trait under study or the point of history at which the study is made.

In [Durham, 1991], it is also pointed out the necessity of subdividing *'large ethnolinguistic populations into the appropriate number of smaller and more homogenous reference groups.'* [Durham, 1991, p. 210]. Culture -Durham says- may be a 'population-level phenomenon' but it often reflects the special interests, desires, and impositions of smaller subgroups within the whole.

Another author that refers to subdivisions of culture is [Goodenough, 1981]. He emphasizes that in addition to several systems of standards in a society's public culture in which all of its members are competent, there are others in which only some members are competent. Some of these systems may be associated with subgroups within the society. We can refer to this level of difference as subcultural and speak of the group as having different *subcultures*. Roughly speaking, we could say that culture is to subculture what language is to dialect and species is to subspecies.

But the necessity of having subdivisions of cultural systems is not present only in works like the above mentioned. The theory of Artifical Social Systems (cfr. [Moses & Tennenholtz, 1995]) considers also the possibility of dividing societies into sub-societies. According to [Tennenholtz, 1995], each agent will be allowed to perform only actions which are not prohibited by the law of its sub-society.

So, it seems, according to all the above mentioned works, that it is important, and somehow necessary, to consider a subdivision of cultural environments into some smaller units that -following the terminology used by some

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of the researchers working in the field of cultural evolution- we could name *subcultures*.

If we add this further division to our model, figure 19.2 will be increased as shown in figure 19.3.

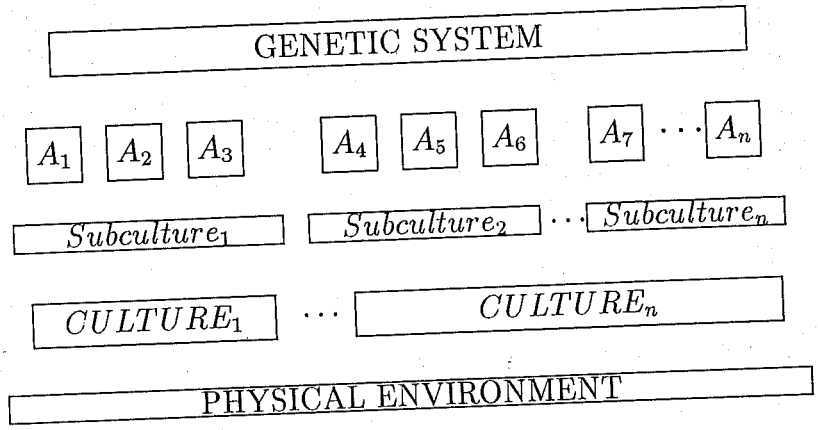

Figure 19.3: Subcultures

19.1.4 Cultural Influence on Biology

> *'The genetic and cultural evolutions of mankind are not independent but interdependent. They are tied together in a system of feedback relationship.'* Dobzhansky.

> *'The human genome could be 'domesticated' by culturally transmitted traits.'* [Boyd & Richerson, 1985, p. 277].

If we look at our model, up to now, we do not have anything else than some boxes standing as agents, and some others standing as biological, cultural,

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subcultural and physical environments, respectively. But, we have talked neither about the relationship among these elements nor about their mutual influences. So, it is time to include some arrow in our picture.

We have said, from the very beggining, that genetics and culture are not two independent inheritance systems, but that they are *interdependent.* This is, somehow those two systems are able to influence or modify each other. As [Maynard Smith & Warren, 1982] point up, it is not so difficult to imagine ways in which genetic and cultural change could reinforce one another. But, let concentrate now in the influence that culture can exert on biological environment.

Any individual belongs to an specific culture, he is living according to some cultural laws and is constrained somehow by the current 'rules' of the culture according to which he is developing his everyday activity. So, if every human being is, by force, inside a culture, we can say that culture provides the environment in which genes are selected. Hence a change (usually very rapid) in culture can cause a (slower) change in gene frequency, and, if genetic constitution of the individuals composing a society influences the nature of a society, then the coevolutionary circuit is complete.

So, we can say that culture can alter somehow the direction and/or rate of genetic evolution. Durham refers to this cultural influence on biology as 'cultural mediation' and explains it in the following way:

> *'The relationship called cultural mediation may be said to exist whenever a cultural change within a population or a cultural difference between two populations causes some difference in the rate and/or direction of genetic evolution. More specifically, cultural mediation occurs whenever a cultural difference in memes within or between populations creates a behavioral difference that, in turn, causes a difference in the reproduction genotypes.'* [Durham, 1991, p. 226].

Therefore, as it follows from the above quotation, the important point is that a cultural difference within or among populations can alter one or more of the acting genetic selection pressures, causing, in consequence, a shift in the direction or intensity of genetic selection. Culture can have this effect on biology in different ways:

- by changing global environmental properties;
- by relaxing natural hazards or reducing disease;
- by redefining diet or subsistence strategy;
- by setting the standards of mate choice, etc.

So, every change in culture can have some effect in biology. In fact, this influence is manifested, for example, in the effects that diet, medical knowledge, values, social relations and other cultural variables have on stature, life expectancy, frequency of specific pathologies, fertility, and other biological differences among individuals and populations.

From all the above follows that we have to relate in our model culture with biology. We have to include an arrow from the cultural systems to the biological environment that will stand for the influence that cultures have in evolution of genetic system. With this new element, our model will look as shown in figure 19.4.

19.1.5 Genetic Influence on Culture

> *'Culture may 'mediate' or modify the differential reproduction of genotypes, and genes may similarly 'mediate' the cultural selection of alternative allomemes.'* [Durham, 1991, p. 205].

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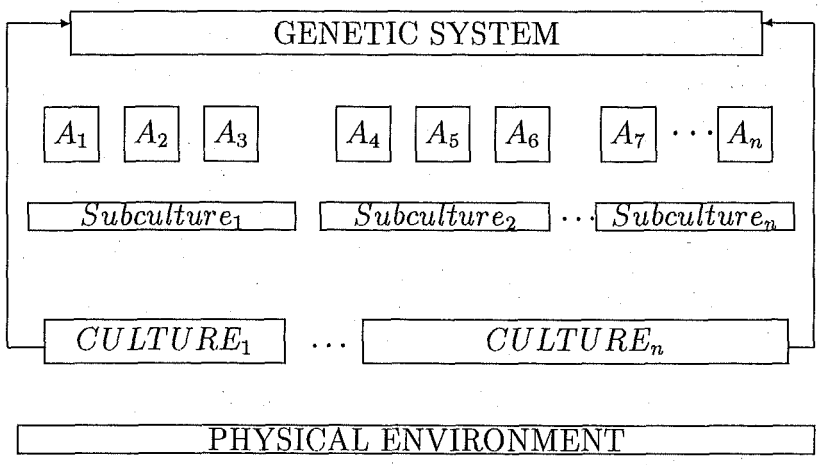

Figure 19.4: Cultural Influence on Biology

In the above section, we have seen how culture can influence evolution of biological system. But, of course, this influence is not one-way, this is, genetic system is also capable of modifying or conditioning somehow changes in culture. As [Gabora, 1997] emphasizes, since many of our needs have a biological basis, meme generation -this is, culture- is largely constrained by our heritage as products of biological evolution. After all, we cannot forget that cultural systems depends upon *organically* -this is biologically- evolved features of human organism.

If in the previous section we have referred to what Durham calls 'cultural mediation,' here we are forced to make reference to what he names 'genetic mediation.' According to Durham, 'genetic mediation'

> *'Refers to situations in which a genetic change within one population, or a genetic difference between two populations, is causally related to a difference in primary values and therefore to a difference in the rates and/or directions of cultural evolution. Obversely, genetic mediation also refers to the situation where*

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genetic similarity of populations is responsible for their cultural similarity.' [Durham, 1991, p. 437].

So, in what ways is culture tied to genes? It is obvious that cultural systems are clearly dependent upon genes in a variety of ways, both physiologically and anatomically. Culture depends on human beings, they are the ones that modify and make culture evolve. Human beings are the products of genetic evolution, so culture depends on genetic changes because it depends on humans and these are directly conditioned by their genetic traits.

This cultural dependence on the genetic environment, across or through agents, is reflected in our model by putting some arrows from the genetic environment to the agents, instead of directly relating biological and cultural systems, as shown in figure 19.5.

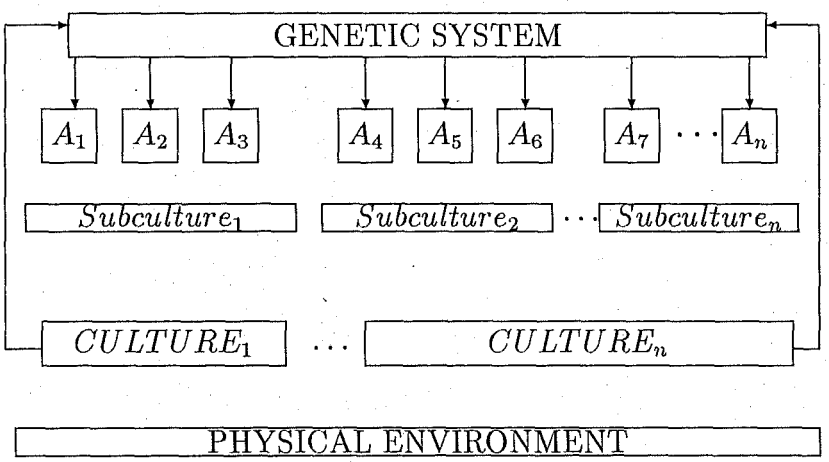

Figure 19.5: Genetic Influence on Culture

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19.1.6 Influence of Culture, Genetics & Environment on Agents

It has been said that populations of *noncultural* organisms have only two sources of behavioral variation:

1. environmental variation, and
2. genetic variation.

According to this idea, two genetically identical populations may differ because they live in different environments, this is to say, the same genetically transmitted developmental program can give rise to different phenotypes in different environments. On the other hand, two populations in similar environments may differ because they have different genetic compositions, either because selection has favored different genotypes in different environments or because of some historical accident, such as random genetic drift.

If we turn now to human populations, we will see that we can explain differences among them in terms of the same two above sources of variation plus an addional one: *heritable cultural variation.* In this case, two genetically identical human populations living in the same environment may behave differently because they have different culturally transmitted traditions. Just to put an example, think of genetically similar individuals from different populations which live in similar environments and that might speak very different languages.

So, according to the above ideas, humans are influenced by three different sources:

1. physical environment,
2. biological environment,

3. and cultural environment.

Importance of the physical environment, and mainly of the adaptation to the environment, has been pointed out by several authors. [Stonier, 1992], for example, measures the intelligence exhibited by a system as a ratio of the ability of a system to control its environment versus the tendency of the system to be controlled by the environment.

Regarding the influence of biology and culture on human beings, it is interesting to cite the distinction established by Pugh (cited by [Durham, 1991]) between two types of values in human decisions:

1. On one hand, *primary values* designed by organic evolution via *genetic selection.* These values develop in each individual out of the interaction between nervous system and environment, and they characteristically require no input from social or cultural transmission. These values - according to Pugh- generally take the form of valuative sensations that are experienced as intrinsically good or bad, pleasant or unpleasant;

2. and on the other *secondary values* that stem not from individual experience and ontogeny, but from collective experience and social history. These include social conventions, moral or ethical principles, habit, etc., that people uses as a practical aid in making decisions. These second values are cultural.

So, according to this typology of values, human decisions -and, therefore, human behavior- are influenced by genes and culture, this by biological traits as well as by cultural features.

Summing up, it is obvious that man may be somehow influenced by the *physical environment* where it lives. It is also clear that genetic environment should have a strong effect on humans beings, not in vain we are the product

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of some biological or genetic evolution. And finally, if man is defined as a social or cultural organism, it may be conditioned by the laws and rules of the culture (and subcultures) to which he belongs. How can we translate all these things in our model? Simple, we have to draw some more arrows:

- we have to put arrows from genetic system to agents, these arrows will stand for the influence that biological environment has in *evolution* of agents;

- we must draw some arrows from subculture to agents, in order to indicate cultural constraints on agents' *actions*. For reasons of simplicity, we will consider that agents are directly constrained by the *subculture* to which they belong, and just indirectly influenced (through the subculture) by culture. Don't forget that, after all, subculture is a subdivision of culture; so by being influenced directly by a subculture, agents are actually influenced by a specific part of culture. This simplification could be justified by adducing that rarely an individual knows everything of his own culture, usually we are able to become acquainted with a small part -this is a subculture- of what constitutes our culture. So, somehow it would more realistic to consider that agents are constrained and influenced by that subpart of their culture that constitutes the subculture to which they belong.

- and finally, we have to draw some arrows that go from the physical environment to the whole system, in order to put in evidence that physical environment constrains evolution of genetic system as well as evolution of agents. And, of course, by influencing evolution of agents, it will constrain indirectly changes on cultural environments, because agents and only agents, as we will see, are the responsible for cultural evolution.

With all these additions our model is increased in the way shown in figure 19.6.

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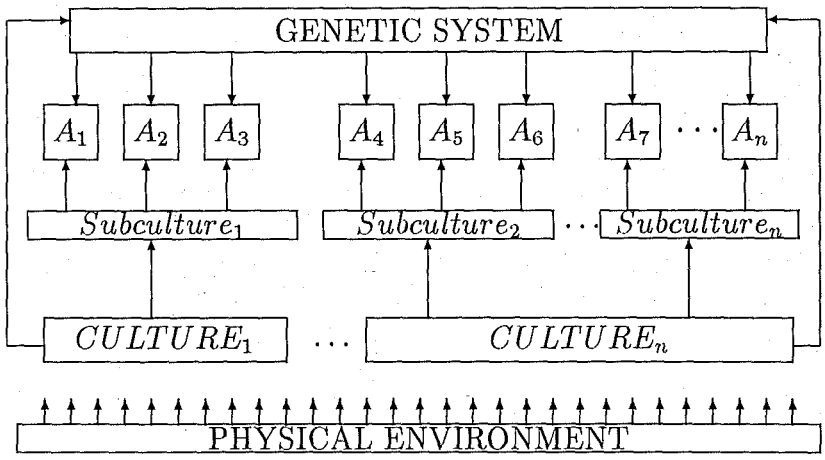

Figure 19.6: Influences on Agents

19.1.7 Changing the Environments

Till now we have presented the elements of our model -agents, biological environment, cultures, subcultures and phsysical environment- and we have seen how they could be interrelated among them -cultural influence on genetics, genetic influence on culture, influence of culture, genetics and environment on agents. Now, it is time to see how the different environments and agents evolve or, what is the same, how they change their states.

But, before entering in the explanation of how different parts of our model evolve, and in order to fully understand the reasons of the different ways of evolution we will establish, it is convenient to say few words about rates of evolution in cultural and genetic systems, and about 'man-made' nature of culture.

Rates of Evolution

'The process of evolution is much slower and cumbersome that

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> *the process of cultural development, which in turn is slower that the process of individual learning.'* [Belew, 1990, p. 45].

The above quotation put in evidence a fact that is recurrently found in the bibliography of cultural change: difference in the rates of evolution between cultural and biological systems[3]. The general idea is that cultural systems evolve faster than genetic ones. Many are the authors that have stressed this point. Reynolds, for example, states that

> *'Cultural evolution enables societies to adapt to their environments at rates that exceed that of biological evolution based upon genetic inheritance alone.'* [Reynolds, 1994, p. 131].

Dennett speaks in the same terms when he says that *'cultural evolution operates many orders of magnitude faster than genetic evolution'* [Dennett, 1995, p. 339]. Also for [Cavalli-Sforza & Feldman, 1981], the rate of cultural evolution should be faster than that of biological evolution. However, these authors recognize that even though cultural change is often thought to be fast relative to biological evolution, some cultural traits are extremely conservative as well. Others authors as [Stonier, 1992], James Neel in [Ortner, 1983] or [Farmer & Belin, 1992] stress the fact that cultural evolution is strinkingly fast when compared to the much slower pace of biological evolution.

It is worth to make reference to the differentiation between rates established by Richard Belew. In [Belew, 1990], the author establishes an important difference between the rates of the three adaptive systems used, according to him, by societies:

(i) learning (individual);

[3]This trait have inspired, for instance, the development of the so-called Cultural Algorithms within the field of Evolutionary Computation.

(ii) culture (society);

(iii) evolution (population).

Evolution is responsive to the most glacial changes, *culture* to more rapid changes, and *learning* to those changes in the environment that can be observed within a lifetime. The resulting, as Belew points out, is an *'environment as a constantly changing wave form, with lower frequency components being tracked by evolution, intermediate frequencies by culture, and the highest frequencies being tracked by learning.'* [Belew, 1990, p. 46].

That culture evolves faster than genetics is obvious if we think that in our lifes we can be witnesses of several cultural changes and rarely we will see any genetic mutation. As Dawkins says,

> *'Fashions in dress and diet, ceremonies and customs, art an architecture, engineering and technology, all evolve in historical time in a way that looks like highly speeded up genetic evolution.'* [Dawkins, 1976, p. 190].

The way in which genetic system evolves is slow and this is because *'as natural selection acts solely by accumulating slight, successive, favourable variations, it can produce no great or sudden modification; it can only by very short and slow steps.'* [Darwin, 1859, p. 380].

According to all these quotations, something is clear: culture evolves faster than genetic system. We have to reflect this feature somehow in our model, and we will do it.

Culture: Man-Made

> *'It cannot be denied that cultural objects are man-made in a sense, or, at least, modified by man. They do not come into existence somehow or other by chance; we do not receive them simply*

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> *from nature; they are created or directed in some way by Human Activity.'* [Vermeersch, 1977, p. 23].

The above quotation puts in evidence that culture is man-made, that man is the responsible for creation and changes in cultural systems. The author puts out some very important ideas about culture: it would not exist without man, it does not exist by chance, it is created and directed by man. But, of course, this author is not the only one that stresses human role in cultural evolution. Almost every scholar that has afforded the study of cultural change has stressed the role of man in this process. For example, Reynolds states that *'culture is a human product in the first place'* [Reynolds, 1984, p. 75]. Haas expresses the same idea when he says that

> *'Agents are the tinkerers in the cultural system. They are the sources of cultural variation. It is also the agents who are making decisions about whether to adopt specific variations and who pass on information from generation to generation.'* [Haas, 1996, p. 20].

Graubard qualifies man as a *'culture-building animal'* [Graubard, 1985, p. 113], while [Bernardi, 1977, p. 76] gives him the qualifier of *'culture maker.'* Cavalli-Sforza and Feldman are very clear when they assert that *'we are all the agents and witnesses, as well as the beneficiaries and victims of cultural change.'* [Cavalli-Sforza & Feldman, 1981, p. 340]. Also for Durham, of course, *'it is people, not 'nature,' who do most of the selecting in cultural evolution.'* [Durham, 1991, p. 458].

The above quotations emphasize the role of man in cultural evolution. All of them point up that individuals change cultural systems. But it is important to stress -as Bernardi does- that

> *'Every intuition, interpretation, or action of an individual, however new, original, and renovating, would become lost, barren, if not taken up by the collectivity, articulated into an organic complex, and transmitted as part of a common inheritance.'* [Bernardi, 1977, p. 78].

That this adoption by the collectivity is so important, can be exemplified by a linguistic example. We can say that any idiosyncratic speech habit certainly introduces *variation*, but *change* in language is only initiated when the new variant is adopted by a group of speakers, when it becomes systematic and acquire some social significance. This is to say, we may assume that a certain word or pronunciation is indeed introduced by one individual in the language just when it becomes part of the language, and it becomes part of the language only when it is adopted by the rest of speakers.

Summing up, man changes culture. Culture cannot evolve without direct action of human beings. This is an important fact when we are trying to describe how culture evolves, and our model intends to do it, so we must somehow reflect this important idea, and we will try to do it.

Differents Ways of Evolving

> *'Evolution is any gradual change.'* Wilson, 1980 (cited by [Ingold, 1986, p. 1]).

What is Evolution? Maybe the best definition of evolution still Darwin's one: *'descent with modification.'* But we can find several definitions of this phenomenon in the literature. One that fits very well with the evolution present in our model is the one quoted above and proposed by Wilson. Anyway, maybe the best way to define evolution is to state what it is not:

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- evolution is not progress or improvement, it is simply cumulative and transmissible change;
- evolution is not genetic selection or 'Darwin's theory,' these are nothing else than ideas about mechanisms of evolution in a specific context, namely, organic evolution;
- evolution is not an exclusive property of genetic systems, many other things can and do evolve.

So, knowing what evolution is not and taking into account the important ideas that have been pointed out in the previous sections to account for different ways of evolution in culture and genetic system, we are ready to face the problem of evolution in our model.

We have seen that culture evolves faster than genetic system, and that it evolves thanks to direct action of agents. In contrast, genetic system evolves in a slower fashion and admits little -or none- direct modification on behalf of man. We have to reflect these important ideas in our model. How to do it? Simple: by drawing some more arrows in our model.

How does culture evolve? To account for the fact that agents are the responsible for change of culture we will draw some arrows from the agents to their subcultures. Why not to draw the arrows from the agent to the culture directly? As we have stated somewhere, we defend the idea that an individual, in principle, do not have knowledge of the whole culture he is inside of. Usually he is able to have acquantaince of a subpart -this is, a subculture- of what constitutes his whole cultural environment. So, by drawing the arrow from agent to subculture, we are putting in evidence the fact that an agent can change his subculture, this is, the part of culture he knows perfectly.

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So, an agent can change his subculture. But how to change the 'big' culture? By drawing some more arrows from subculture to culture, we are accepting the idea that every subculture -as a group- can introduce modifications in culture. The idea will be the following: first some changes are introduced by agents into subcultures, and some of these modifications, when they are already accepted by the collectivity of subculture, can enter to form part of culture as a whole, conditioning in this way actions, not only of the subculture who first introduced the change but, of every subculture that forms part of that culture. Therefore, changing a specific subculture or changing directly the whole culture[4], the result is the same: it is man who changes culture. Culture cannot evolve alone.

How does genetic system evolve? Unlike culture, genetic system does not accept direct action of agents. So, to account for its evolution we cannot resort to agents' actions. Change in genetic system occurs in a very different way. It evolves by his own rules, addmiting just some weakly influence of cultural systems. Notice that by evolving according to own rules instead of by direct actions of agents, we are somehow stressing the difference in rates of evolution. Culture will evolve much faster than genetic system, because culture counts with the help of agents to change, while genetics depends only on some special rules, rules that are very slow as recognized by Darwin when he explicitly states *'The natural selection will always act with extreme slowness, I fully admit.'* [Darwin, 1859, p. 89].

How does physical environment evolve? We have stressed the idea that environment is somehow external to population itself and that environmental conditions are not strongly affected by changes in the popu-

[4]As it will be shown in the formal definition, we allow agents to act directly in the *culture*, but just in those symbols of the string not affected by the subculture as a whole.

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lation. But at the same time, we have pointed out that man -even though being constrained by the environment where he lives and being obligated to adapt to the conditions of the environmental system- is not just a 'slave' of its environment, but he actively modifies it. So, to account for this duality in the evolution of environment, we will consider that environment changes according to its own rules, that are somehow 'external' to the rest of the system -in the sense that they are not constrained by anything else- but at the same time we allow agents to weakly modify the state of the environment, conditioning in this way the direction of its evolution.

How do agents evolve? We have seen that individuals are constrained by everything they have around. Evolution of man will be conditioned by genetic system as well as by physical environment where he lives. At the same time, agents will be heavily constrained by culture they belong to. Culture and subculture will directly rule actions man will perform in their everyday activity. Summing up, genetic system and environment constrain agent's evolution, and culture and subcultures constrain agents actions.

All the above will be reflected in our model by adding some more arrows, as shown in figure 19.7.

19.2 Formalizing the Model

In the previous section we have built our model in a progressive way, introducing step by step all the elements it may contain and trying to establish the relationship that may exist among them. But in the introduction of this part, as well as in the rest of the dissertation, we have stressed the formal theoretic nature of the new models proposed in this thesis. Cultural Grammar

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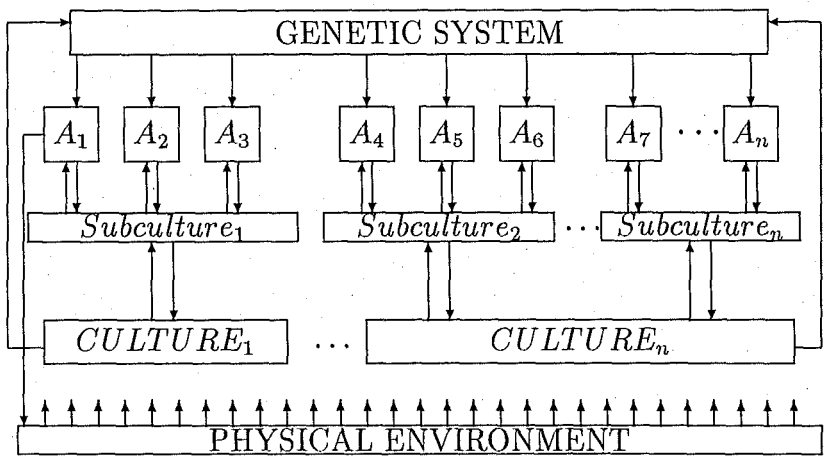

Figure 19.7: Changing the Environments

Systems is not a exception. We want to have a formal-language theoretical framework to study cultural change. So, now, we have to go one step further and formalize -using Formal Language Theory- the above model. The formal model we will present in this section satisfies all the conditions pointed out in the informal model presented above and summarized in figure 19.7. Formalization we will carry out in this section implies, of course, a high level of abstraction.

19.2.1 Elements Making up the Model

We have established in the above section that Cultural Grammar Systems are made up by five important elements:

1. a physical environment,
2. a genetic system,
3. a set of cultures,

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4. a set of subcultures,

5. a set of individuals or agents.

So, our formal model should reflect in their definition these five components. But taking into account that we are formalizing a model, and that formalizing means abstraction, we will reduce the definition of Cultural Grammar System to an n+2-tuple like the following:

$$\Sigma = (E, G, C_1, \ldots, C_n),$$

where E stands for the *physical environment*; G denotes the *genetic system*, and $C_1, \ldots, C_n$ represents the set of cultural systems.

So, if we have three components in our formal definition, where are the other two elements of our above intuitive model? We will consider that a *culture* is a set of *subcultures*, and that, in turn, a *subculture* is a set of *agents*. This will be formalized as follows:

$$C_i = \{K_{i_1}, \ldots, K_{i_{r_i}}\},$$

$1 \leq i \leq n$, $r_i \geq 1$,

$$K_{ij} = \{A_{ij1}, \ldots, A_{ijs_{ij}}\},$$

$1 \leq j \leq r_i$, $s_{ij} \geq 1$,

where C_i is the i-th cultural system with subcultural systems $K_{i_1}, \ldots, K_{i_{r_i}}$, and K_{ij} denotes the j-th subcultural system of cultural system C_i with agents $A_{ij1}, \ldots, A_{ijs_{ij}}$.

The above formalization respresents an abstraction, as we have already said. But in some way, this abstraction can be justified by a real circumstance. We have said somewhere that culture is man-made, we have stressed very

much the idea that without individuals culture would not evolve nor change. It is also an obvious fact that culture is nowhere, but in each individual who follows and lives according to some specific rules, laws, habits, customs. At the same time, we have said that people does not know everything in their cultures, but just a small part of them that we have called, following some authors, *subcultures.* So, subcultures, as cultures, cannot be found in any specifc place, but in the minds of individuals. Taking all these facts into account, a possible abstraction is the following: what is a subculture? nothing but a group -or a set- of agents that share some rules, habits and customs (remember that subcultures are nowhere but in each individual); and what is a culture? again, nothing else that a group of subcultures that have enough things in common that allow for their grouping in a single culture and that, at the same time, make them different enough from other subcultures for not being in the same cultural system. So, summing up, we can say that *individuals* have some rules -or knowledge- according to which they behave. If the knowledge of several agents is similar enough, they constitute a subgroup -this is, a *subculture*- of the whole population. That group of agents will act attending the laws, customs and habits of their subculture. If there are two -or n- subcultures similar enough, they can be grouped in the same *culture.* Therefore, if we follow now the opposite way, we will say that any *culture* is a set of *subcultures.* And any *subculture* is a set of *agents.* In this way we justify the following definition of a Cultural Grammar System.

By a Cultural Grammar System of degree n, where $n \geq 1$, (shortly, by a CG-system) we mean an $n+2$-tuple

$$\Sigma = (E, G, C_1, \ldots, C_n),$$

Let see, now, how to formalize each of the elements that make up *Cultural Grammar Systems.*

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19.2.2 Physical Environment

When we have talked about physical environment in the above section, we have stressed so much the idea that it is somehow external to the population, and that it evolves according to its own dynamics, that is quite independent on individuals and cultural and genetic systems. So, according to this idea of independent change of physical environment, we have to include in its formalization some device to account for that evolution. A well choice, we think, could be to include a set of context-free rules that will be applied in an 0L manner. We remind that Lindenmayer systems are formal language theoretic models for developmental systems, and because of that they can account well for the evolution processes in our model.

Since physical environment could not act directly (this is with action rules) on any of the elements of the system, but just evolve according to its evolution rules, we think that its formalization will come down to the following:

$$E = (V_E, P_E),$$

where

- V_E is the alphabet of environmental states,
- P_E is a complete finite set of context-free rules over V_E, the so-called *evolution rules* of E.

19.2.3 Genetic System

We turn now to genetic system. When we have included genetic system in our model, we have insisted on the idea that it evolves according to some own special rules. At that time we wanted to contrast such way of evolving with

evolution of cultural systems. Therefore, if genetic system has its *own* evolution rules, we have, somehow, to formalize those rules in our definition. But, we have also pointed out that genetic environment can be *weakly* constrained by the state of cultural systems. We have emphasized the idea that culture can modify somehow the direction of genetic evolution. So, we should reflect this cultural influence on genetics in our definition. How to do it? We have chosen to divide the set of evolution rules (P_G) in two parts:

1. a complete finite set of pure context-free rules (P_G^1), that are the basic rules determining evolution of genetic system;

2. an a finite set of rules (P_G^2) of the form

$$(\alpha_1, ..., \alpha_n) : A \to v$$

where $\alpha_i \in V_{C_i}^*$, $1 \leq i \leq n$, and $A \to v$ is a pure context-free rule over V_G, that describes how cultural systems can constrain genetic evolution.

Notice that since P_G^1 -the set of basic evolution rules- is *complete*, the influence of cultural systems described by P_G^2 is a weak one, as we have emphasized many times in the previous sections.

Summing up, genetic system can be formalized as follows:

$$G = (V_G, P_G),$$

where

- V_G is the alphabet of genetic system,

- $P_G = P_G^1 \cup P_G^2$ is the set of *evolution rules*, where

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- P_G^1, is a complete finite set of pure context-free rules over the alphabet V_G, and contains the basic rules determining evolution of genetic system,
- and P_G^2, is a finite set of rules where each rule is of the form $(\alpha_1, \ldots, \alpha_n) : A \to v$, where $\alpha_i \in V_{C_i}^*$, $1 \leq i \leq n$, and $A \to v$ is a pure context-free rule over V_G, and describes how cultural systems can constrain genetic evolution.

19.2.4 Cultures and Subcultures

We have already advanced, above, that in our formal definition a *culture* is just a set of subcultures and, in turn, a *subculture* is a set of agents. We have formalized this as

$$C_i = \{K_{i_1}, \ldots, K_{i_{r_i}}\},$$

$1 \leq i \leq n$, $r_i \geq 1$,

$$K_{ij} = \{A_{ij1}, \ldots, A_{ijs_{ij}}\},$$

$1 \leq j \leq r_i$, $s_{ij} \geq 1$,

where, of course, C, K and A stand for culture, subculture and agent, respectively.

As it follows from the above denotation, we do not consider a set of rules neither for cultures nor for subcultures, in contrast with what was the case for physical and genetic environments. What is the reason for that?

Culture -and, in the same way, subculture since it is nothing else that a subdivision of culture- does not need neither evolution rules nor action ones. Remember that we have emphasized so much the fact that culture cannot

evolve alone as genetic system or physical environment do. We have stressed the idea that to evolve, culture needs the actions of agents on its string, that there is no way of changing cultural state but by means of human activity. So, if this is the case, we do not need to define any set of evolution rules for culture and, consequently, we do not do it!

It has not sense, either, to define a set of action rules for culture as we will do for agents. And, it has not sense because culture cannot *act* on anything. Culture is nothing else than a conglomerate of habits, customs, traditions or 'laws' that guide the actions of people living according to its postulates. Remember that it is the *state* of culture -this is, a string that contains symbols denoting conventions, customs, laws, etc.-, and not a finite set of rules, the one that constrains agents and drives their actions. To understand what we mean, it is worth to make a parenthesis to explain the difference between *culture* and *behavior* and the notion of *'social law'* introduced by Moshe Tennenholtz. At the end of this brief parenthesis we will be able, I hope, to see why we do not consider a finite set of context-free rules for culture.

Culture versus Behavior

> *'Culture is best seen not as complexes of concrete behavior patterns -customs, usages, traditions, habit clusters- as has, by and large, been the case up to now, but as a set of control mechanisms -plans, recipes, rules, instructions- for the governing of behavior.'*
> Geertz (cited by [Durham, 1991, p. 9]).

Several anthropologists, among them Geertz, Goodenough, Hall, Schneider, Wallace, point out that culture consists not of behaviors or even patterns of behavior, but rather of *shared information* or knowledge encoded in *systems of symbols.*

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We have seen, when we have reviewed definitions that have been proposed for *culture*, that several scholars in the field have defined culture in terms of patterns of behavior. But, it is very important to stress that *culture* cannot be confounded with *behavior*. It is true that culture provides a set of expectations regarding what kinds of behavior are suitable in given situations. But it is also true that in few situations -just, ritualized ones- it is possible to predict precise behavior. People often violate the expectations a culture provides, so, even accepting the fact that culture helps to make behavior much more predictable that it would be otherwise, we have to avoid the *equiparation of culture and behavior*.

It is so important to establish a difference between culture and behavior because, even though, elements that make up culture - ideas, values, beliefs, and the like- certainly help to organize and shape human behavior, they are logically and empirically distinct from *actions* themselves. Culture, thus, should be thought of -as is pointed out in [Durham, 1991]- not as behavior but as a part of the information that specifies its form. After all, that culture is not behavior can be justified by adducing that culture is but one of several guidance systems which can influence the nature and form of human behavior. Genes as well as the natural and social environment constitute, of course, other guiding forces.

Summing up, if culture is not behavior, culture is not *action*. So we do not need any set of rules to account for actions of culture, because there is not such action. But if culture, is not action, how can it be defined? Which could be the adequate notion -or a more or less adequate notion- to account for that set of ideas, values, beliefs and the like that form culture?

Social Laws

In our model we want culture to be something able to constrain and guide actions of agents, something able to restrict somehow their everyday activity, but, at the same time, something susceptible of being modified and changed by agents themselves. A close idea is the so-called *social law* introduced by Tennenholtz (cfr. [Shoham & Tennenholtz, 1995, Tennenholtz, 1995] [Tennenholtz, 1996, Tennenholtz, 1997, Shoham & Tennenholtz, 1997]).

Theory of *Artificial Social Systems*, presented in [Moses & Tennenholtz, 1995], provides a framework in which agents will be able to plan, act, and thereby manage to satisfy their goals. The work on *artificial social systems* concentrates on the off-line design and computation of laws that will enable each agent to work individually and successfully towards its own goals during the on-line activity, provided that the other agents obey these laws. The thesis of Moses and Tennenholtz is that a society metaphor has an important role to play in this context. Their work is presented as the first to discuss explicitly and formally the computational mechanism that applies for non-centralized intermediate solutions.

Wherever we have a multi-agent system -be they human societies or distributed computing systems- involving many agents that operate in a shared environment and where actions of one agent can affect success of another agent's activities we face a coordination problem. In such distributed systems, it is crucial that agents agree on certain rules, in order to decrease conflicts among them and promote cooperative behavior. Two have been the traditional possible solutions for those coordination problems:

1. *Central Coordination or Centralized Approach.* It assumes a single central controller who must worry about all the possible interactions among agents and that specifies behavior of agents at each point in time. This is the approach taken in Robotics.

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2. *Decentralized Approach or Negotiation Mechanism.* Here agents work individually in an unconstrained fashion and as a result conflicts may appear. Research concentrates on designing mechanisms to equip agents with the means for handling these interactions during execution, this is, mechanisms for conflict resolution. This approach is common in Distributed AI literature.

These two possibilities present some limitations:

- in the first -'central coordination' approach- agents' behavior is fully dictated by the centralized control, leaving no freedom to the individual agent. Although there are situations where such a solution might be effective, it is obvious that this approach is unrealistic and infeasible for many situations;
- in the second approach -the 'decentralized' one- agents are assumed to be totally free and independent.

An intermediate approach to coordination to solve these limitations is proposed by Tennenholtz: one in which to adopt a convention, a *'social law.'* If each agent obeys the convention, we will have avoided every conflict without any need for either a central arbiter or negotiation. Theory of social laws, thus, relaxes restrictions of those above extreme solutions and, instead it strikes a good balance between allowing freedom to individuals programmers on the one hand, and ensuring cooperative behavior among them, on the other. Notice that in this approach many of the above-mentioned conflicts do not even arise, since they are resolved during the initial design of the system.

Roughly speaking, Artificial Social System Theory is a basic mechanism of coordination that bridges the gap between a totally centralized approach and a purely decentralized approach to coordination. The major purpose of

these systems is, of course, to keep agents from reaching conflicts to begin with, wherever possible.

But, what is a social law? A *social law* (for a formal definition, cfr. [Shoham & Tennenholtz, 1995]) is a set of restrictions on agent's activities which strikes a balance on the one hand, allowing agents enough freedom to achieve their goals, and on the other hand, restricting them so that they will not interfere with each other. So, in an Artificial Social System, society will adopt a set of laws; each agent will be required to obey these laws and will be able to assume that all the others will as well; these laws will, on the one hand, constrain the plans available for agent, but on the other hand will guarantee certain behaviors on the part of other agents. Intuitively, social law will determine which strategies are 'legal' and which are not. It is important to emphasize -as [Tennenholtz, 1997] does- that social laws determine standards of behavior rather than specific behaviors.

From all the above follows that culture is not behavior -this is, culture is not action- but a guide system, a control mechanism, a set of shared information encoded in systems of symbols that somehow controls behavior, that drives *actions* of agents. Culture is made up by 'social laws,' this is, by restrictions of the set of available actions to a set of socially allowed actions.

So, if culture is not action, it has not sense to define a set of context-free rules for cultural systems. In our model, culture should be something different from a set of rules. Culture is a *string of symbols* created, changed, modified and cancelled by agents. It is man who builds culture -we have said-, culture is a human product, cultural objects are created and directed by human activity. In our model, agents generate the string of culture, they are the responsible to create, change and modify the *string representing the state of culture*. Culture in our model is not a set of rules -as it is the case for agents, for example- culture is a string of symbols generated by agents, but a string of symbols with a strong power. Do not forget that culture -the string

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of symbols representing it, in our model- has to, and effectively does, restrict, constrain and direct human activity. So, in our model agents' actions are constrained by the state of cultural environment (we will define a mapping to represent these constraints), they have to adapt their action choices to the current state of culture. They cannot apply whatever rule they want to, they have to check first which is the state of their culture in order to know which are the allowed actions at that moment of time.

Summing up, if culture -and in the same way, subculture- is not action, it does not need *rules* to be applied anywhere. And if culture cannot evolve alone, it has no necessity of having *evolution rules* to account for any change. So, in our formalization, cultures and subcultures do not contain any set of context-free rules and they are defined just as follows:

$$C_i = \{K_{i_1}, \ldots, K_{i_{r_i}}\},$$

$1 \leq i \leq n$, $r_i \geq 1$,

$$K_{ij} = \{A_{ij1}, \ldots, A_{ijs_{ij}}\},$$

$1 \leq j \leq r_i$, $s_{ij} \geq 1$,

naturally, of course, with their own alphabet -shared by culture i-th an all the subcultures K_{ij} under its influence- denoted by V_{C_i} and over which will be defined agents' context-free rules used to modify the state of cultures and subcultures.

Before ending this section, we have to say something about the relation of a cultural system and its subcultural systems: we will assume that the string representing the state of the cultural system contains as a subword the concatenation of the strings representing its subcultural systems, where subcultural states are concatenated in the order of growing indices. The idea beyond is that culture is in some sense a superposition of its subcultures.

19.2.5 Agents

We are to undertake in this section one of the most important elements of our model: *agents.* We have emphasized many times the idea that culture cannot evolve without the action of man. We have stressed in several places along this chapter, that human beings are the responsible for cultural evolution, because they are the ones that use and modify culture in their everyday activity. We have recognized, also, that humans are able to modify their physical environment. At the same time, we have pointed out, that man is constrained by its genetic inheritance, by its culture and by the physical environment where he lives. So, man -agents, in our model- is subdued to all around him. But at the same time, he has the capacity of acting on almost everthing around him.

As it follows from the above characteristics, man or 'agents,' as we call them in our model, will have a very complicated structure in the formal framework we want to define. Let us summarize what we need for each agent:

- something to account for its *evolution*;
- something to represent *actions* agents can perform on *physical environment*;
- something to account for actions agents can perform on their respective cultural systems;
- and something that allows agents to modify their subcultures.

Once more we will use context-free rules to account for actions agents can perform in the different environments, as well as for their evolution, however, in the last case we will apply rules in an 0L fashion.

But we have said that agents are not free to perform any action they want to, either in physical environment or in cultural and subcultural systems. We have emphasized very much the idea that cultures and subcultures constrain actions of human beings. We have stressed, also, the fact that evolution of agents is not free, but it depends very much on the state of genetic system as well as on features of physical environment. We have pointed out, as well, that agents can modify the environment -taking into account what the environmental state is. So, somehow we have to account for all these constraints in our formal model. The easiest way to do so, in a formal language framework, is by using *mappings.*

Formally, an agent of a Cultural Grammar System will be defined as follows:

$$A_{ijk} = (V_{ijk}, P_{ijk}, R^E_{ijk}, R^{C_i}_{ijk}, R^{K_{ij}}_{ijk}, \psi_{ijk}, \phi^E_{ijk}, \phi^{C_i}_{ijk}, \phi^{K_{ij}}_{ijk}),$$

$1 \leq i \leq n$, $1 \leq j \leq r_i$, $1 \leq k \leq s_{ij}$,

where

- V_{ijk} is the *alphabet* of the agent;
- P_{ijk} is a complete finite set of pure context-free rules over alphabet V_{ijk}, that represents the set of *evolution rules* of the agent and that are applied in an 0L manner;
- R^E_{ijk} is a finite set of pure context-free rules over alphabet V_E, that describes *actions* agent can perform on *physical environment*;
- $R^{C_i}_{ijk}$ is a finite set of pure context-free rules over alphabet V_{C_i}, that stands for *actions* an agent can perform on current state of *cultural system* C_i;

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- $R_{ijk}^{K_{ij}}$ is a finite set of pure context-free rules over alphabet V_{C_i} that represents *action rules* an agent can use to modify the state of *subculture* K_{ij};

- $\psi_{ijk} : V_E^* \times V_G^* \rightarrow 2^{P_{ijk}}$ is a *mapping* that determines, according to *current states of physical environment and genetic system*, how agent will evolve or, what is the same, which evolution rules can be used in that moment;

- $\phi_{ijk}^E : V_{ijk}^+ \rightarrow 2^{R_{ijk}^E}$ determines, according to current *state of agent*, the set of *action rules* available at that moment for him to modify *physical environment*;

- $\phi_{ijk}^{C_i} : V_{ijk}^+ \times V_{C_i}^* \times V_{C_i}^* \rightarrow 2^{R_{ijk}^{C_i}}$ is a *mapping* that, according to current *state of agent* and taking into account the state of *cultural system* C_i, as well as current string of *subcultural system* K_{ij}, determines the set of *action rules* from which agent can choose one to perform an action on the state of *cultural system* C_i to which it belongs;

- $\phi_{ijk}^{K_{ij}} : V_{ijk}^+ \times V_{C_i}^* \times V_{C_i}^* \rightarrow 2^{R_{ijk}^{K_{ij}}}$, this *mapping* establishes, according to current *state of agent*, *state of cultural system* C_i and *state of subcultural system* K_{ij}, the set of *action* rules from which agent can select one to be applied on the state of *subculture* K_{ij}.

With this formalization, we have captured all the activity that can be performed by an agent, as well as every constraint to which he is subdued. We have reflected in the formal definition how the *evolution* of an agent depends on genetic system as well as on environment where he lives. We have captured the idea that agents can act on physical environment as well as on cultural and subcultural systems. Notice, that according to what we have defended in previous chapter, we do not allow agents to act directly on genetic system, they do not have any set of rules to act on it.

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Notice that when we define the mapping that determines which actions an agent can perform on physical environment we take into account just the *state of agent* and not current state of the environment. This could seem a countersense, but it is not. We do not consider state of physical environment in that mapping, because we have already considered it in evolution of agent. The idea is the following: state of the environment (together with state of genetic system) will guide evolution of agent, that will enter (because of this evolution) in a specific state that, in turn, will constrain the action it will apply on physical environment. So, by considering influence of environment on evolution of agent we are already taking into account state of the environment in the selection of actions an agent will perform on physical environment. State of agent alone will determine those actions, but state of agent is the one it is because of the influence of the environment. So, there is no countersense in that mapping, but just the will of avoiding redundancy: if we have already considered the state of the environment in the evolution of the agent, why to take it into account once more?

Notice also that, according to the above definition, an agent can act either in its cultural system or in its subcultural system, because it has two sets of rules, one for each type of system. Remember that when we have been speaking about cultures and subcultures we have said that, in principle, agents act only, or basically, on their subcultures and that changes in subcultures may affect the state of culture -being culture something like a superposition of subcultures, and containing as a *subword* of its state string the concatenation of the strings representing its subcultural systems. However, to be more realistic we could reformulate that idea, and say that agents, effectively, act principally on their subculture, because this is the part of their culture they know best, but they can also modify the state of the *whole culture* to which they belong, because, even though, culture contains as a subword the concatenation of every subculture under its control, it has other things (other

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symbols in our model), this is, other rules, laws, customs, habits etc. that do not constrain any subgroup (or subculture) in particular but that are common to the whole population under that specific culture. Summing up, a culture is more than the sum of all the subcultures it has in its inside, there are 'social laws' common to the *whole* culture, and these 'social laws' (symbols in our case) are in the *state of culture* (not in an specific subculture) and can be, of course, modified by agents who live according to those rules. So, agents can modify both: cultures and subcultures.

A necessary simplification we have assumed in the formalization of our model is the fact of considering that an agent belongs to exactly *one* subculture and *one* culture and, of course, he can act only on its *own* cultural and subcultural systems. This is, if an agent A_1 belongs to culture C_1 and to subculture K_{1_1} it cannot act on any different culture or subculture from those and, at they same time, it will not be constrained by any other cultural system. This is, of course, a big simplification if we take into account that in the real world there are lots of cases in which people know -and therefore is able to change and act according to- many cultural traditions, speak more than one language, etc. But to formalize implies inevitably some degree of simplification, at least by now!

19.2.6 State of Cultural Grammar System

We have talked repeatedly of *state* of cultural system, influence of *state* of genetic system on agents, *state* of subculture, evolution of *state* of an agent, modification of *state* of physical environment. So, it is in order to define formally what we understand by the *state* of *Cultural Grammar System* (and therefore, of each of its elements) at any given moment.

If we consider a Cultural Grammar System $\Sigma = (E, G, C_1, \ldots, C_n)$, $n \geq 1$, the *state* σ of Σ is a 5-tuple of arrays as the following:

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$$\sigma = (M_E, M_G, M_A, M_K, M_C),$$

where

- $M_E = (w_E)$, where $w_E \in V_E^*$ is the current *state* of the *environment*;
- $M_G = (w_G)$, where $w_G \in V_G^*$ is the current *state* of the *genetic system*;
- $M_A = (\gamma_{ijk})$, $1 \leq i \leq n$, $1 \leq j \leq r_i$, $1 \leq k \leq s_{ij}$, where $\gamma_{ijk} \in V_{ijk}^*$ is the current *state* of *agent* A_{ijk};
- $M_K = (\beta_{ij})$, $1 \leq i \leq n$, $1 \leq j \leq r_i$, where $\beta_{ij} \in V_{C_i}^*$ is the current *state* of *subcultural system* K_{ij} or the state of the $(ij)-$th subculture;
- $M_C = (\alpha_i)$, $1 \leq i \leq n$, where $\alpha_i \in V_{C_i}^*$ is the current *state* of *cultural system* C_i or the state of the i-th culture, and for every i, $1 \leq i \leq n$, $\beta_{i1}\beta_{i2}\ldots\beta_{ir_i}$ is a substring of α_i.

As it follows from the above definition, the state of each element of our system -physical environment, genetic system, agents, subcultures and cultures- is denoted by a string of symbols over the corresponding alphabet. Notice that, as we have pointed out in the previous section, the state of a cultural system contains as a subword the concatenation of the states of its subcultural systems.

Up to now, we have formally defined every element that makes up a Cultural Grammar System as well as its *state* at any given moment. Thus, definitions we have already provided give a static description of our formal framework. Its time now to provide a dynamic view of the model, and to do so we have to define how Cultural Grammar System changes its states.

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19.2.7 Evolution of Physical Environment

When we have defined *physical environment,* we have said that it evolves by its own *evolution rules* that are independent on the state of any other component of Cultural Grammar System. But at the same time, we have accepted the idea that *agents* can weakly modify current state of environment by performing some weak actions on its string. So, according to these ideas, there are two ways in which the string representing current state of physical environment can be changed or modified:

1. by means of *weak actions* performed by agents;
2. and by means of its own *evolution rules.*

These two different forms of evolving of the physical environment are formalized as follows.

Let $M_E = \{w_E\}$ and $M'_E = \{w'_E\}$ be two states of physical environment. Suppose that

$$w_E = z_0 A_0 z_1 \dots A_m z_{m+1},$$

where $A_l \in V_E$, $0 \leq l \leq m$, $z_t \in V_E^*$, $0 \leq t \leq m+1$.

Then,

$$w'_E = z'_0 u_0 z'_1 \dots u_m z'_{m+1},$$

where $A_l \to u_l \in \phi^E_{ijk}(\gamma_{ijk}) \subseteq R^E_{ijk}$, for some i, j, k where $1 \leq i \leq n, 1 \leq j \leq r_i, 1 \leq k \leq s_{ij}$, and the rules $A_l \to u_l$, $0 \leq l \leq m$, are performed by m different agents. Strings z'_t, $0 \leq t \leq m+1$, are obtained from strings z_l by applying rules of P_E in the $0L$ manner.

So, as it follows from the above definition, physical environment state is modified both by *weak actions* of some active agents at some places (by

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application of rules of the form $A_l \to u_l$ from the set R^E_{ijk}, and allowed by the mapping $\phi^E_{ijk}(\gamma_{ijk}))$, and by its own *evolution rules* (by application of rules from P_E in a 0L fashion) at some others. Notice that each active agent is allowed to perform exactly one action.

With those two ways of evolving we have formally accounted for the way of changing one of the components of our Cultural Grammar System, namely *physical environment.*

19.2.8 Evolution of Genetic System

In the case of genetic system, we have said that it evolves according to its own *evolution rules* that are independent on every component of the system. However, we have recognized somewhere 'cultural mediation' on genetic evolution, this is, we have accepted some *weak* influence of current state of cultures on the way of evolving genetic system. Taking into account that this cultural influence should be very 'soft,' we think that maybe the best way of representing it is not the *mapping*, that could somehow give us the idea of a 'heavy' genetic dependence on culture. We think (and we have reflected it in definition of genetic system) that a better solution to formally account for that 'weak' influence is to consider that the set of *evolution rules*, P_G, of the genetic system is the *union* of two different sets of rules:

1. P^1_G, a complete finite set of pure context-free rules that contains the basic rules determining the evolution of the genetic system;

2. and P^2_G, a finite set of rules of the form $(\alpha_1, ..., \alpha_n) : A \to v$, where $\alpha_i \in V^*_{G_i}$, $1 \leq i \leq n$, and $A \to v$ is a pure context-free rule over V_G, that describes how the cultural systems can constrain genetic evolution.

According to this division of the set of *evolution rules*, we formalize the change of the state of the genetic system as follows.

Let $M_G = \{w_G\}$ and $M'_G = \{w'_G\}$ be two states of genetic system. Suppose that

$$w_G = A_0 A_1 \dots A_m,$$

where $A_l \in V_G$, $0 \leq l \leq m$.

Then

$$w'_G = y_0 y_1 \dots y_m,$$

where for each $A_l \to v_l$, $0 \leq l \leq m$,

(i) either $A_l \to v_l \in P^1_G$,

(ii) or for some u_i, $1 \leq i \leq n$, u_i is a substring of α_i, the state of cultural system C_i, and $(u_1, \dots, u_n) : A_l \to v_l$ is a rule in P^2_G.

As it follows from the above definition, evolution of genetic system can take place due to its basic evolution rules (P^1_G) and without any 'foreign' influence or due to evolution rules *weakly constrained* by cultural systems (P^2_G).

Notice, that since we do not define a mapping to select evolution rules of genetic system according to the state of cultural environments, we are not forcing genetic system to check the state of cultures before any evolutionary step, and in this way we emphasize the 'weakness' of cultural mediation on genetic evolution.

19.2.9 Evolution of Agents

When we have talked about evolution of agents, we have defended the idea that agents evolve according to some *evolution rules*. Application of those

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evolution rules depends, we have said, very much on state of genetic system (genetic inheritance) as well as on current state of physical environment where agents live. To account for that influence we have defined a mapping (ψ_{ijk}) that, taking into account both state of genetic system and state of physical environment, determines which rules (from the set of evolution rules of agent, P_{ijk}) can be used to change the *state* of agent at any given moment.

So, taking all the above into account we will formalize the change of state of any given agent as follows.

Let $M_A = (\gamma_{ijk})$ and $M'_A = (\gamma'_{ijk})$, $1 \leq i \leq n$, $1 \leq j \leq r_i$, $1 \leq k \leq s_{ij}$ be two states of the k-th agent. Then γ'_{ijk} is obtained from γ_{ijk} by applying rules in $\psi_{ijk}(w_E, w_G) \subseteq P_{ijk}$ in the $0L$ manner.

Notice that, as in the case of evolution in genetic system and phsyical environment, we apply the rules in a 0L manner.

19.2.10 Evolution of Culture and Subculture

We face now the evolution or change of the state of cultures and subcultures. Up to now, whenever we have defined evolution of a component of our system, we have always had a set of rules to account for that change. In the case of physical environment, we had a set of evolution rules that determined the change of the environmental state. The same could be said for genetic system and agents. But, now, we have to account for change of cultures and subcultures states, without having any set of rules within those systems to carry out the task. So, we have to define the evolution of cultural and subcultural environments in a different way.

We have repeated several times along this chapter that cultural objects are man-made and that any change in culture (and therefore, in subcultures) is due to *action* of man. So, if we want to formally define evolution of the

state of a culture or subculture we have to refer to actions agents perform on cultural and subcultural strings. So, I repeat once more, the only way culture has for evolving is by means of direct agents' actions on its string. This idea will be captured in the following definitions.

Let $M_K = (\beta_{ij})$ and $M'_K = (\beta'_{ij})$, $1 \leq i \leq n$, $1 \leq j \leq r_i$ be two states of the j-th subculture. Suppose that

$$\beta_{ij} = y_0 B_0 y_1 \ldots B_m y_{m+1},$$

where $B_l \in V_{C_i}$, $0 \leq l \leq m$, $y_t \in V^*_{C_i}$, $0 \leq t \leq m+1$, $1 \leq j \leq r_i$. Then

$$\beta'_{ij} = y_0 v_0 y_1 \ldots v_m y_m,$$

where $v_l \in V^*_{C_i}$, $0 \leq l \leq m$, $1 \leq j \leq r_i$, and $B_l \to v_l \in \phi^{K_{ij}}_{ijk}(\alpha_i, \beta_{ij}, \gamma_{ijk}) \subseteq R^{K_{ij}}_{ijk}$ for some k, $1 \leq k \leq s_{ij}$, moreover, the rules $B_l \to v_l$, $0 \leq l \leq m$, are performed by m different agents.

Let $M_C = (\alpha_i)$ and $M'_C = (\alpha'_i)$, $1 \leq i \leq n$ be two states of the i-th culture.

Let $u = \beta_{i1} \ldots \beta_{ir_i}$ and let $u' = \beta'_{i1} \ldots \beta'_{ir_i}$, where $\beta'_{ij} \in V^*_{C_i}$, $1 \leq i \leq n$, $1 \leq j \leq r_i$ is the state of the subcultural system K_{ij} determined above. Suppose that

$$\alpha_i = x_0 A_0 \ldots x_{l-1} u x_l A_l \ldots A_m x_{m+1},$$

where $A_t \in V_{C_i}$, $0 \leq t \leq m$, $0 \leq l \leq m$, $x_h \in V^*_{C_i}$, $0 \leq h \leq m+1$. Then

$$\alpha'_i = x_0 v_0 \ldots x_{l-1} u' x_l v_l \ldots v_m x_{m+1},$$

where $A_t \to v_t \in \phi^{C_i}_{ijk}(\alpha_i, \beta_{ij}, \gamma_{ijk}) \subseteq R^{C_i}_{ijk}$, for some j, $1 \leq j \leq r_i$, and k, $1 \leq k \leq s_{ij}$, moreover, the rules $A_t \to v_t$, $0 \leq t \leq m$, are performed by m different agents.

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Notice that since subcultural systems determine somehow the state of their cultural system[5] -any change in subculture will have some effect on culture-, the change of the state of the cultural system follows the change of the state of its corresponding subcultural systems. This is, first, agents perform some actions on the state of their subcultures and, then, they apply action rules to those places on the culture's state that have been not affected by the change in the state of subcultural systems.

Notice that with this way of accounting for changes in culture and subculture, and mainly by allowing agents to change either cultural or subcultural systems, we are keeping our original idea that culture is not just the concatenation of subcultures, but that culture has additional symbols (i.e. customs, habits, laws) not specifically contained in any subculture. So, agents can act both on their subcultures -changing their states and having these evolution consequences for the state of culture- and on their cultures. To act on any of these two types of environment and to change them, agents will have to take into account which is the current state of subculture, which is the state of culture and which is their own state. According to all these parameters, agents will know which rule to apply in any moment (mappings $\phi_{ijk}^{K_{ij}}(\alpha_i, \beta_{ij}, \gamma_{ijk}) \subseteq R_{ijk}^{K_{ij}}$ and $\phi_{ijk}^{C_i}(\alpha_i, \beta_{ij}, \gamma_{ijk}) \subseteq R_{ijk}^{C_i}$, specify the selection of rules).

19.2.11 Evolution of Cultural Grammar System as a Whole

We have analyzed one by one the evolution of the states of each component of Cultural Grammar System. Obviously, evolution of the whole Cultural Grammar System is defined as the change of the state of each of its components.

[5]Remember that we have considered that the string of culture contains as a subword the concatenation of the strings of its subcultures.

So, formally

Let $\Sigma = (E, G, C_1, \ldots, C_n)$, $n \geq 1$, be a Cultural Grammar System defined as above. Let $\sigma_1 = (M_E, M_G, M_A, M_K, M_C)$ and $\sigma_2 = (M'_E, M'_G, M'_A, M'_K, M'_C)$ be two states of Σ defined as above. We say that *state* σ_1 *directly enters* into *state* σ_2, written as $\sigma_1 \Longrightarrow \sigma_2$, if and only if all the conditions we have put to change the states of the environment, genetic system, agents, subcultures and cultures hold (cfr. sections 19.2.7, 19.2.8, 19.2.9, 19.2.10).

Usually, in Formal Language Theory, the 'output' of any formal language theoretic device is, obviously, a *language*. We should define, following this rule, the language generated by Cultural Grammar System because we are dealing with a grammatical machinery. But, for our present purposes, we prefer, instead of defining the language generated by the system, to describe the functioning or development of Cultural Grammar System in terms of sequences of states. So we will define the set of state sequences of Cultural Grammar System $\Sigma = (E, G, C_1, \ldots, C_n)$ starting from its *initial state* σ_0 as

$$Seq(\Sigma, \sigma_0) = \{\sigma_i\}_{i=0}^{\infty},$$

where $\sigma_i \Longrightarrow \sigma_{i+1}$, $i \geq 0$.

Our first motivation has been to provide a formal language theoretic framework to account for *cultural change*. Since the very beginning, we have been interested in formally defining the *way* in which culture evolves. In other words, we have been interested in the *process* of changing culture rather than in the final *result* of the evolutionary process. For that reason, we retain more useful, for our present purposes, to define the sequence of states of the system rather than to define the language generated by Cultural Grammar System. If we define a *sequence of states*, we will see which different states of the system in its progressive evolution have been, this is, we will know *how* we have arrived from state σ_0 to state σ_n, we will know what has happened

in between those two different states, we will know the *process* of change. If we just define the *language* generated by the system, the only thing we will know is that from σ_0 we have obtained σ_n, but we will ignore which has been the way of passing from one state to the other, we will know the *result*, but not the *process*, and we are, precisely, interested in the latter one rather than in the former.

However, even though we present here only the definition of the set of state sequences, since components of Cultural Grammar Systems determine sets of strings, we can associate languages to our formal framework, as well.

19.3 Bringing together Picture & Definitions

In the above section, we have formally defined each of the elements that make up Cultural Grammar Systems as well as evolution of each of them, explaining and somehow justifying every formalization. In this section, we just want to put together all the above definitions, in such a way of having an overall view of that formal framework for cultural change, that we have called Cultural Grammar Systems.

As it is usual in Formal Language Theory, we will first give a static description of our formal framework by describing the components that make up the system; secondly, we will present the dynamics of the model by describing the direct derivation of the system; and finally, instead of defining the language generated by the system, we will define its development in terms of set of state sequences, for the reasons we have adduced in the above section. We will end this section with an example of Cultural Grammar Systems.

Before starting to present formal definitions, we remind, once more, the simplifications we have assumed:

- actions of agents correspond to applications of pure context-free rules;