Analogies in Scientific Explanations: Concept Formation by Analogies in Cultural Evolutionary Theory[*]

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Abstract

In philosophy of science concept formation and reduction is usually discussed with respect to definability. In the paper at hand this discussion is slightly expanded to an investigation of concept formation and reduction by analogies. It is argued that many kinds of such analogies bear some important features of partial contextual definitions.

With the help of a detailed investigation of the so-called gene-meme-analogy it is then demonstrated how the 'meme'-concept is introduced via analogies into an expanded theory of (cultural) evolution. As a consequence it is shown that the diversity of meanings of the 'meme'-concept fits into the current state of establishing this analogy.

12.1 Introduction

[209] In this paper we investigate a paradigmatic case of introducing concepts into theories via analogies. We will do so by concentrating on the controversial discussion about the meme-gene-analogy in cultural evolutionary theory.

An almost self-suggesting question regarding theories of cultural evolution concerns their very basic notion: How could meme theories explain diversity in culture, if cultural evolutionary theorists disagree so widely about the meaning of the basic vocabulary of their theories, especially about the meaning of the expression 'meme'? A more explicit argument underlying this question can be stated as follows:

1. Gene theories allow us to explain diversity in nature.

2. Meme theories aim at an explanation of diversity in culture.

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3. Some people think that memes are "the software of the brain".

4. Other people think that memes are all kinds of information stored in brains, libraries, computers, states of affairs etc.

5. Hence, since 'meme' is a basic notion of cultural evolutionary theories, this diversity in meaning prevents the theory of cultural evolution from providing an explanation of diversity in culture.

Obviously this is no logically valid argument, but one may consider the premises of the argument as providing convincing reasons for the conclusion of the argument. In the following sections we will argue against such a view by showing that, although the expression 'meme' is used quite ambiguously by cultural evolutionary theorists, the concepts of cultural evolutionary theories are introduced by analogies allowing such a diversity without lack of precision, but at the cost of specificity in the sense of high informational content.

[210] In order to keep technicalities quite general, we limit our investigation to a very rudimentary description of concept formation by analogies (section 12.2). We will then present the analogy between natural and cultural evolution used by cultural evolutionary theorists (section 12.3). We will do so in a three-fold step: First we present a general form of the analogy (12.3.1). Then we present a formalized form and discuss the analogy in more detail (12.3.2). And finally we will show that the analogies drawn in this area allow for a quite diverse meaning of the expression 'meme' (12.3.3).

12.2 Concept Formation by Analogies

In scientific explanations and descriptions analogies and conclusions by analogies are frequently used. Indicators for analogical reasoning and analogical use of language are comparing phrases as, e.g., 'similar as', 'likewise', 'analogically' etc. A very common analogy within science is the comparison of water in a pipe with current in a conductor. A shortened analogical description of this example would be 'Electric current in a conductor is like water in a pipe.' Take, e.g., the law of Hagen-Poiseulle (L1) and Ohm's law (L2):

L1 $p_1 - p_2 \equiv \frac{V}{c}$ $\qquad\qquad$ (V…volume of fluid, c…speed, p_i…pressure)

L2 $v_1 - v_2 \equiv \frac{I}{k}$ $\qquad\qquad$ (I…amperage, k…conductance, v_i…potential)

As one can see, both laws run straightforward analogously. Now, it is well known that c varies indirectly proportional with the length of the pipe:

L3 $c \sim \frac{1}{l_1}$ $\qquad\qquad$ (l_1…length of the pipe)

Analogical to this fact it holds that k varies indirectly proportional with the length of the conductor:

L4 $k \sim \frac{1}{l_2}$ $\qquad\qquad$ (l_2…length of the conductor)

So there is also another regularity running straightforward analogously in the source and the target domain. Furthermore it holds that:

L5 $V \sim r_1^4$ ($r_1 \ldots$ radius of the pipe)

And so the question arises whether there holds also a similar regularity in the target domain? But here one can show that it only holds (not similarly) that:

L6 $I \sim r_2^2$ ($r_2 \ldots$ radius of the conductor)

[211] Analogical usage of language about two different domains (e.g., physics of liquids and electromagnetism) is given here in the sense that some descriptions of regularities are syntactically isomorph, that is: $V \mapsto I$, $c \mapsto k$, $p_i \mapsto v_i$ and vice versa.

Already with the help of this example the main problem of analogical usage of language can be stated quite easily: Which descriptions of regularities within one domain of investigation are adequately adoptable for descriptions of regularities within another domain of investigation?

The simplest and up to now most accepted solution to this problem is a restrictive definition (cf. Hempel 1970, p.434): Instead of defining 'expression e_1 is analogue to expression e_2' one just defines 'expression e_1 is analogue to expression e_2 with respect to regularity φ'. According to this solution it holds, e.g., that I is analogue to V with respect to L1 and L2, but not with respect to L5 and L6.

To make a little bit more technical sense of such a characterization we define a (partial) one-one mapping *is* on the language under investigation. Let's assume a standard first-order language $\mathcal{L}$, containing the usual connectives and logical signs $\sim$, & (the other connectives are assumed to be introduced by the usual meta-linguistic conventions), $\forall$, $\equiv$, $x_1, \ldots$ as well as terms and predicate signs $t_1, \ldots, P_1^n, \ldots$ (for all $n \in \mathbb{N}$) in the vocabulary. Then we characterize *is* for the descriptive vocabulary as follows (for all $n, m \in \mathbb{N}$):

- $is(t_n) \in \{t_i : i \in \mathbb{N}\}$ (where individual variables are mapped by the identity relation)

- $is(P_m^n) \in \{P_i^n : i \in \mathbb{N}\}$

And then generalize *is* inductively:

- For all atomic formulas $P^n(t_1, \ldots, t_n)$: $is(P^n(t_1, \ldots, t_n)) = is(P^n)(is(t_1), \ldots, is(t_n))$

- For all terms t_1, t_2: $is(t_1 \equiv t_2) = is(t_1) \equiv is(t_2)$

- For all formulas φ: $is(\sim \varphi) = \sim is(\varphi)$

- For all formulas φ, ψ: $is(\varphi \& \psi) = is(\varphi) \& is(\psi)$

- For all formulas φ and variables x: $is(\forall x \varphi) = \forall x is(\varphi)$

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(We also assume that the signs of arithmetic stay, like the logical signs, unchanged by *is*.) With such a mapping it holds for our example of fluid physics and electromagnetism above that $is(I) = V$, $is(v_i) = p_i$, $is(k) = c$ and $is(l_2) = l_1$. And so we can describe the analogical relation between these two domains simply by the regularity claims: L1→ is(L1), L3→ is(L3). And these analogical relations can be restated logically equivalent as:

- L1→ $(is(\text{L1}) \leftrightarrow \text{L1})$

- L3→ $(is(\text{L3}) \leftrightarrow \text{L3})$

which may be seen as conditionalized contextual definitions of: I, k, v_i and l_2. To generalize this formulation: If e_1 and e_2 are analogue with respect to $\varphi[e_2]$ (where the [212] square brackets after a formula around an expression serves here just as an indicator for the occurrence of the expression in the formula), then e_1 is introduced with the help of e_2 and $\varphi[e_2]$ by partial contextual definitions of the form:

$$\varphi[e_2] \rightarrow (is(\varphi)[e_1] \leftrightarrow \varphi[e_2])$$

The concept formation by analogies is only contextual since the usage of an expression is not clarified at the level of the signs of the vocabulary, but only at the level of formulas. And the formation is only partial since the usage is only clarified in contexts for which the analogy is assumed to hold, so it is conditioned on the source analogy.

One may note that there are two main problems with such a characterization of concepts: Firstly, there is the problem of distinguishing contextual definitions from any other kind of non-definitional axioms. Since we provide no further analysis of the contexts of such characterizations, one cannot draw an exact borderline between these two kinds of creative and non-eliminative theory-extension. But for our purposes of an analysis of the gene-meme-analogy in cultural evolutionary theory we do not need such a further analysis of the context—we will point out very general structural properties characterized by the gene-meme-analogy here only. And secondly, there is the problem of a conditionalized multiple characterization of an expression by analogical concept formation. Take, e.g., the regularities L1–L4 of the example above. If L2 and L4 are regarded as a contextual definition of structural properties between concepts of electromagnetism, conditioned on the relevant regularities of fluid physics L1 and L3 respectively, then, e.g., the relational properties of conductance k are characterized multiple times. In cases where the conditions of such a characterization are logically exclusive, a multiple characterization does no harm to a theory's consistency. On the contrary, it even increases eliminability of k in more contexts. But in cases where the conditions are not logically exclusive, such a characterization my end up with inconsistencies within the expanded theory and by this is harmful. Also this problem will be not treated here further because in our application to the gene-meme-analogy we will have to do with a conditioning on exactly one regularity only.

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12.3 The Gene-Meme-Analogy

Richard Dawkins spends one highly influential chapter (chpt.11) for a—also to his mind—quite speculative analogy in his book *The Selfish Gene* 1976 in which he elaborates the idea that the basic units for evolutionary investigations should be neither populations nor single organisms, but replicators like genes. The mentioned analogy is the so-called gene–meme–analogy which was since then used widely and very controversial in cultural evolutionary theory. In the following three subsections we will give a general sketch of the analogy, provide a formalization of it and finally discuss the diversity of the analogical characterization of the expression 'meme' in the context of the given formalization.

12.3.1 General Form of the Analogy

[213] In order to extract the general form of the analogy, we first have to characterize—although very sketchily—the source domain of the analogy, namely natural evolution.

One insight Charles Darwin achieved during his detailed investigations of lots of biological species is the idea that in constructing biological models for describing the development of species one should take care of at least three parameters, namely a parameter for replication, one for variation and one for selection:

> "Darwinian theory's [...] essential elements are simply replication, variation and selection. If these requirements are met then evolution seems bound to happen. If organisms reproduce, passing their characteristics almost (but not always quite) accurately on to the next generation, and if their environment does not supply them with unlimited resources for their survival, then they will evolve[.]"
> (cf. Distin 2005, p.2)

So, according to Darwin's theory of evolution (*The Origin of Species*, 1869) there are three conditions needed to be satisfied within a system in order to count as a system of evolution (cf. Schurz 2011, p.192):

1. *Reproduction*: There are subsystems or organisms which reproduce themselves with respect to some important properties. These properties are called 'reproduced or inherited properties' and every process of reproduction creates a new generation.

2. *Variation*: The reproduction leads to variation which is also inherited.

3. *Selection*: There is selection, because some variants are fitter under the given environmental circumstances than others, i.e.: They reproduce themselves faster than others. By this some other variants are eliminated in the long run. The selecting parameters of the environment are called '*selection parameters*'.
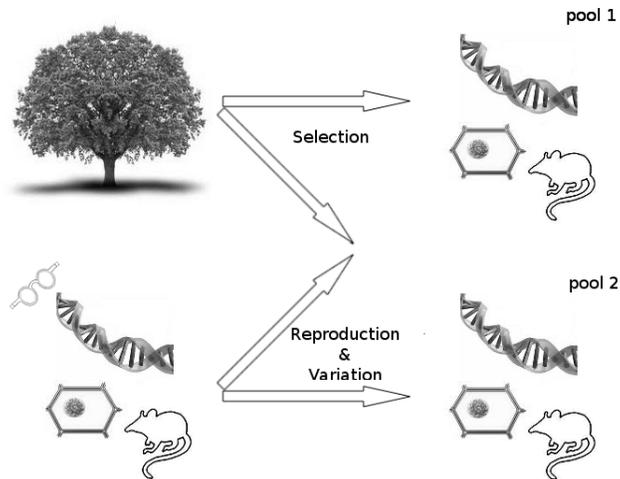
Figure 1: Rudimentary Schema of Natural Evolution: The development of a population is influenced by a selection parameter (in general determined by the habitat the population lives in), a variation parameter (including variation through recombination and variation through mutation) and a parameter for reproduction (including information about the distribution of different properties among the species).

So, the schema of the source analogy may be symbolized as in figure 1. Sometimes also another condition for a system to be an evolutionary system is stated: In order to establish some complexity and regularities in an evolutionary system, a further condition is needed:

4. *Stability*: For directed evolution also a fourth condition, the condition of stability of the selecting forces is needed. This means that the changing rate of the selecting forces is little with respect to the generation rate (cf. Schurz 2011, p.192).

We will be quite undecided here whether this condition should hold for evolutionary systems or not since in the general discussion of the gene-meme-analogy this condition for the source domain is not expanded to the target domain.

Since we have indicated the most relevant parts of the source domain of the analogy here, namely that of natural evolution, we can try now to expand these parts to the target domain, namely cultural evolution! Dawkins' main idea in *The Selfish Gene* was to ground the investigations of the conditions for systems of natural evolution at the level of genes. Reproduction, variation, and selection (especially fitness) is not only considered with respect to whole organisms, but with respect to genes. So, in Dawkins' theory the replicators are of main importance. According to his view, organisms are their "devised

survival machines".

[214] A typical way of expanding a successful theory is to expand its domain. In the words of Dawkins: "Darwinism is too big a theory to be confined to the narrow context of the gene." (Dawkins 2006, p.191). But if the theory of natural evolution should be expanded to other domains as, e.g., the domain of culture, then, in the replicator-centered view of Dawkins, one also needs a more general and expanded form of a replicator. And especially in order to illustrate a universal and substrate-neutral replicator-centered theory of evolution, Dawkins introduced the expression 'meme'. So the idea was to widen the domain of evolutionary theory from $D = Set\ of\ genes$ to $D = Set\ of\ genes\ and\ memes$. Since then many philosophers and scientists interested in cultural theory joined the programme of expanding basic parts of the theory of natural evolution to a theory of cultural evolution. Important figures within this programme are, e.g.: Dawkins (cf. Dawkins 1976), Daniel C. Dennett (cf. Dennett 1992), Susan J. Blackmore (cf. Blackmore 1999), Robert Aunger (cf. Aunger 2000) and Gerhard Schurz (cf. Schurz 2011).

We should also mention here that an expansion of the domain by new replicators is not the only possible and performed way of widening evolutionary theory. An alternative expansion of natural evolutionary theory to a theory of cultural evolution is attempted, e.g., within sociobiology. Alternatively to the introduction of new replicators it was tried to cope with cultural evolution by some kind of reductionism which allows one to reduce cultural phenomena to biological ones. Founding father of this movement was Edward Wilson with the main idea to try to find genetic patterns whose "extended phenotype" are cultural properties.

[215] The main difference between sociobiology and meme-theories of cultural evolution is that whereas in sociobiology the phenotypes are settled at the neuronal level and the replicators within an evolutionary system are genes, in memetics the phenotypes are settled at the cultural level and the replicators are memes. Before we go on with the description of some more general parts of the target domain of the gene-meme-analogy, we just mention two important problems for the reductionistic programme of sociobiology: First, there is a shortage of material in the reductionistic programme, since genetically there are too less combinations possible to cope with electrochemical states of multiple neurons by base pairs. And second, there are too high differences in the speed of the processes going on in natural and cultural evolution in order to be adequately coped by the reductionistic programme, since cultural evolution is too fast in order to become manifest in natural evolution (cf. Distin 2005, p.15) .

As was pointed out by Alex Mesoudi, Andrew Whiten, and Kevin N. Laland and is depicted in figure 2, also in favour of the programme of meme-theories of cultural evolution is the fact that many more or less established disciplines of cultural theory can be mapped almost directly in analogy to a discipline of evolutionary biology.

The general form of the gene-meme-analogy consists in a mapping of the replicators of natural evolution, the genes, to the replicators of cultural evo-
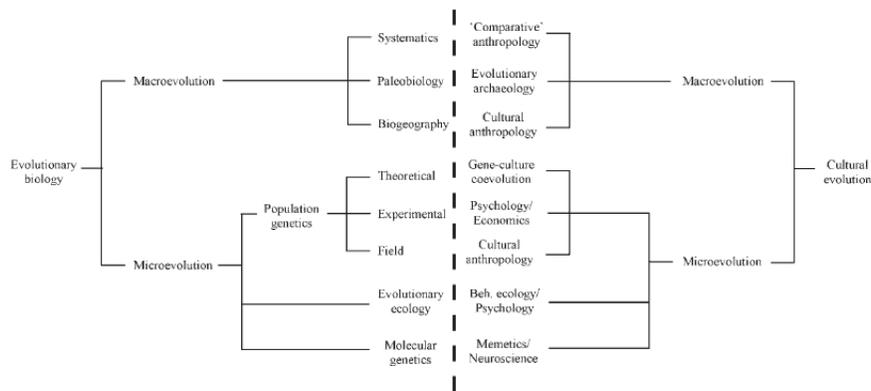
Figure 2: Major subdivisions within evolutionary biology and corresponding disciplines of cultural evolution (Mesoudi, Whiten, and Laland 2006, p.331)

lution, the memes. Based on this mapping is the mapping of parameters. Whereas there is a parameter for reproduction, variation and selection in the source domain, there are also assumed analogous parameters for reproduction, variation and selection in the target domain. So, in constructing models for cultural phenomena one should seek for parameters of cultural reproduction, cultural variation and cultural selection acting on memes.

In order to find such parameters it is convenient to have a more or less concrete characterization of memes available. Although—and this is sometimes stressed by cultural evolutionary theorists against the criticism on the diversity of the interpretation of their basic concepts—also in natural evolutionary theory successes could be observed without a detailed knowledge of genes and their reproduction and variation behaviour, the natural evolutionary programme got a really boost since the [216] gene-system was discovered and investigated on a chemical basis. Cultural evolutionary theorists hope to achieve a similar boost by clarifying the notion of a meme. But until now they are far away from a clear and concrete characterization of this notion—and this not only due to the diversity of an understanding of the expression 'meme'. Here is a list of the quite different meanings (and objections made against them) used by the most important followers of the cultural evolutionary programme:

- *Imitable entities*: Memes are all things that are capable of being imitated. (cf. Dawkins 1976) and (cf. Blackmore 1999):

  > "We need a name for the new replicator, a noun that conveys the idea of a unit of cultural transmission, or a unit of imitation. 'Mimeme' comes from a suitable Greek root, but I want a monosyllable that sounds a bit like 'gene'. I hope my classicist friends will forgive me if I abbreviate mimeme to meme.

> [...] It should be pronounced to rhyme with 'cream'. Examples of memes are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or of building arches." (cf. Dawkins 1976, p.192)

Blackmore:

> "Memes are not best understood as semantic information stored in brains, but rather, as whatever is imitated or copied in culture." (Susan Blackmore in her comment "Why we need memetics" to Mesoudi, Whiten, and Laland 2006, p.349)

and: memes are independent of brain activity etc. because they are also "selfish":

> "Memetic evolution constructed human brains and is now building better, higher fidelity meme machines, including computers, the Internet, and digital media. For the moment we humans are essential to the further evolution of the memosphere, but there are already many memes created that never have contact with a human being, and there will be more." (Susan Blackmore in her comment "Why we need memetics" to Mesoudi, Whiten, and Laland 2006, p.350)

- *Information*: Memes are acquired information, also storable outside of the brain, as, e.g., in books and computers (cf. Dennett 1992):

> "Equivalent to the genotype-phenotype (or replicator-interactor) distinction in culture [...] we can speak of culturally acquired semantic information stored in brains as replicators and the expression of that information in behaviour or artefacts as their interactors." (cf. Mesoudi, Whiten, and Laland 2006, p.344)

Contra: Meme-phenotype-distinction becomes vague.

- *Brain dispositions*: Memes are dispositions of the brain to store (represent) information and cause behaviour (cf. Schurz 2011, p.213).
Contra: Incoherent meme-histories:

> "if there were only minds and no external RS [(Representation System)] in which information could more permanently be stored, then memetic replication would lose much of its present stability." (cf. Distin 2005, p.90)

- *Brain software*: Memes are software parts of the brain (cf. Dawkins 1982, p.109)
[217] Contra: Too early stage of neuroscience

- *Neuromemes*: Memes are electrochemical states of multiple neurons, so-called 'neuromemes', i.e. configurations in one node of a neuronal network that is able to induce the replication of its state in other nodes (cf. Aunger 2000)

  > "Aunger (2002) has recently attempted to integrate memetics with neuroscience, arguing that a robust conceptualisation of the 'meme' must specify its material basis in the brain. He proposes that memes should be seen as electrochemical states of multiple neurons, and offers a definition of a 'neuromeme' as 'a configuration in one node of a neuronal network that is able to induce the replication of its state in other nodes'." (cf. Mesoudi, Whiten, and Laland 2006, p.343)

  Contra: Too early stage of neuroscience

Although there is such a diversity of meanings, almost all proponents of cultural evolution agree in the following desiderata for an explication of the 'meme'-notion:

- *Reproducibility:* They must be reproducible, not only syntactically understood, which would be mechanistically, but also semantically, e.g. by imitation, but more generally by social learning activities as teaching etc. (cf. Distin 2005, chpt.4). Compare also Dawkins' condition of *fecundity* of a replicator

- *A not too high variation rate:* Their variation rate must not be too high. Cf. Dawkins' test: An order—e.g., in a drawing—must be recognizable (cf. Distin 2005, p.104). Compare also his condition of *copying fidelity* of a replicator.

- *A not too low variation rate*: If the variation rate is too low, e.g. in almost perfect information copy machines as computers, then evolution comes to a standstill.

So the criticism that the very basic notion of cultural evolutionary theory is too diverse to be fruitful can be, at least for the moment, answered by a core meaning of this notion consisting in the—obviously very general—property of being reproducible and adequately variable. Nevertheless the programme of cultural evolutionary theory is not as uncontroversial as the "canonization" above might feign. Other and here not further discussed criticism of this programme can be summarized as follows (cf. Mesoudi, Whiten, and Laland 2006, p.343):

- *Discernibility:* Culture cannot be divided into discrete units (cf., e.g., Maurice Bloch)
  Contra:

> "However, the same putative 'criticism' could equally be lev-
> elled at modern concepts of the gene. [...] The concept of
> the gene has undergone significant changes through the past
> 150 years. The classical view, held from the time of Mendel
> (1866) until the 1930s, [also] saw the gene as an indivisible unit
> of transmission, recombination, mutation, and function." (cf.
> Mesoudi, Whiten, and Laland 2006, p.343)

And:

> "Already, one can perceive the beginnings of what has been
> called a 'social cognitive neuroscience' that aims to integrate all
> the required levels of analysis." (Mesoudi, Whiten, and Laland
> 2006, p.343) [218]

- *Dissimilarities:* They outweigh similarities to a very high degree.

- *Generality:* Similarities are too general in order to be fruitful.

- *Terminology doubling:* Meme-talking is redundant. What we need is only
  to talk about the "phenotypes" as usual.

- *Inadequate Framework*:

> "Mathematical models are potentially as useful for culture as
> for evolution, but cultural models must have different designs
> from genetic models. Social sciences must borrow from biol-
> ogy the idea of modelling, rather than the structure of models,
> because copying the product is fundamentally different from
> copying the design." (Bruce Bridgeman in his comment "It is
> not evolutionary models, but models in general that social sci-
> ence needs" to Mesoudi, Whiten, and Laland 2006, p.351)

To summarize this section we mention again that the main part of the gene-
meme-analogy's source domain are the parameters reproduction, variation
and selection in constructing models for the development of populations (con-
sidered at the level of genes). One extension of natural evolution to cultural
evolution is the programme of sociobiology which tries to explain cultural
phenomena reductionistically by showing that they depend on specific genetic
patterns. Two main drawbacks of sociobiology are the problem of less mate-
rial for genetically coding cultural information and the problem of adequately
coding rapid cultural evolution by quite slow natural evolution. An alterna-
tive proposed by Dawkins is an extension of the domain of natural evolution
to a domain also containing cultural replicators, namely memes. In favour of
such a research programme is the fact that many disciplines of cultural theory
can be mapped to analogous theories of biology. But when it comes to a clari-
fication of the meme-concept, then the scientific community disagrees widely.
Nevertheless there are two properties of memes it agrees on, namely the prop-
erty of being replicable and the property of being adequately variable. Besides

the critique that these are very general properties, there is also further heavy critique against the programme of cultural evolutionary theory as mentioned directly above.

Before we come to our formalization of the gene-meme-analogy in the next section, we make a short excursus that should—although only very marginally—support the programme of cultural evolution.

Excursus: Fruitfulness of the Expansion for Natural Evolution?

As we have mentioned already in the introduction, cultural evolutionary theorists hope to explain within this research programme cultural diversity and cultural phenomena similar successful as natural evolutionary theorists did explain diversity of species. Nevertheless it is very often criticised that this programme doesn't add anything substantial to cultural theory. So it is argued that cultural evolutionary theory is useless for cultural theory. In this excursus we will concentrate on another direction, namely on the question whether an expansion of natural evolutionary theory to a cultural evolutionary theory could be of some use for biology? [219] (This question concerns the topic of importing theses about the (originally) target domain of an analogy into the (originally) source domain of the analogy which is to invert the target and source domain of an analogy.)

It is not uncommon in the philosophy of biology to consider the most relevant part of a gene to be the information stored in it and the change of information to be the relevant place of seeking exact parameters for reproduction, variation and selection (for a critical discussion of this view and references cf. Mahner and Bunge 1997, chpt.9.3.4). But this view of evolution seems to come concrete only in investigations that show how to parametrize models according to information stored in genes. One such an investigation is provided, e.g., in (Vitányi et al. 2008, p.53). The idea of Paul M. B. Vitányi et al. is to achieve a measure of semantic closeness via a complexity and information measure. For our purpose we don't have to go into much detail, but the procedure is as follows: Some data is binary coded and evaluated according to its complexity measure, where the complexity of a binary sequence is measured by the possibility of describing the sequence in a shorter way within a specific description (compression) system. The less short a description of a binary sequence is, the more complex it is (try, e.g. to describe the sequences $s_1 = 011011\ldots$ and $s_2 = 0101\ldots$ within a description system offering only operations for reading and writing a value (*val*), accessing the successor (′) of the nth place (starting: 0) and the boolean operations of negation ($\sim$) and conjunction (&)—solution in the footnote[1]). By measuring the distance between the complexity of binary sequences, one ends up with an information distance measure (assumption:

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[1]The shortest description of s_1 within the description system is $val(0) = 0; val(0') = 1; val(n'') = \sim(val(n)\&val(n'))$; with the length 46. The shortest description of s_2 within this description system is $val(0) = 0; val(n') = \sim val(n)$; with the length 25. So s_1 is more complex than s_2.

the more similar the complexity of some data is, the more similar is the information stored in the data). And with the help of such an information distance measure one can try to cluster data. An interesting result of Vitányi et al. is
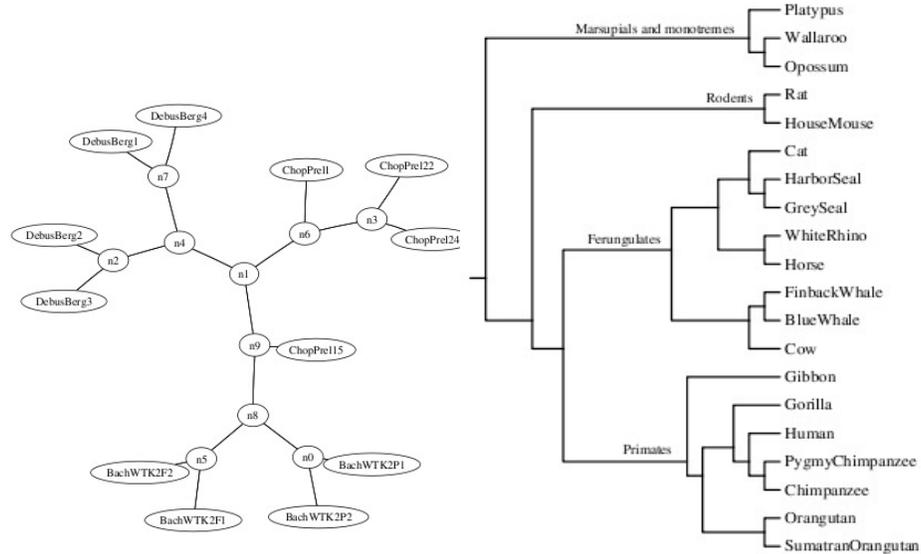

Figure 3: Successful ordering of music pieces (Vitányi et al. 2008, p.53)

Figure 4: Successful ordering of genetic dependency (Vitányi et al. 2008, p.51)

that also by binary coding the chemical information of the DNA of different species, applying the above procedure of measuring the complexity as well as the information distance and then order the data according to these measures one ends up with an adequate tree about the origin of species. Figure 4 depicts such an ordering of species due to the provided information measure. Figure 3 depicts an ordering of music pieces with the help of this information measure.

The point to be highlighted here is that by inverting the source and target domain of the gene-meme-analogy one may also end up with new theses that are relevant for the theory of natural evolution. Memes, interpreted as (genetic) information, and reproduction, variation and selection parameters for informational content may serve somewhere along the way for clarifying, e.g., traditional classification problems of biology etc.

12.3.2 Formalization of the Analogy

[220] We have seen in the preceding section that the gene-meme-analogy makes essential use of the reproduction, variation and selection parameters of natural

evolution. In this section we will consider very briefly a formalization of the interdependence of these parameters. We start with a slightly modernized form of Mendelian genetics: According to Mendelian genetics inheritable properties of organisms are twofold: for every such property there is a phenotype representing the property in question which is based on a genotype. Take, e.g., the phenotype eye-colour which we consider her simplified in the sense that we distinguish only brown-eyed beings from blue-eyed beings. This phenotype is based on the genotypes AA, Aa (aA, the order doesn't matter) and aa via the genome and the diploid chromosome set (one part from the mother and one part from the father)—as mapped in table 1:

Phenotype	> Genome > Diploid chromosome set >	Genotype
Brown-eyed		AA, Aa
Blue-eyed		aa

Table 1: A simplified phenotype-genotype mapping

A and a represent here the so-called alleles (located at the same genetic locus). An upper-case letter represents the dominance of an allele against its amending [221] lower-case allele. So in our example A is dominant against a and a is recessive against A. Such a dominance was measured, e.g., by Mendel when he reared red and white homozygotic pea (via self-fertilization) and crossed them. Since every such crossing ended up with red offspring in the first generation he concluded that the red characteristic was dominant against the white one.

The mixture of genetic material of both parents is called 'meiosis'. Since meiosis is going on randomly (i.e. the frequencies are independent) it holds that the probability of each genotype is as follows: $p(AA) = p(A) \cdot p(A)$, $p(aa) = p(a) \cdot p(a)$ and $p(Aa) = 2 \cdot p(A) \cdot p(a)$, where, e.g., '$p(AA)$' represents the probability that the genotype is AA and '$p(A)$' the probability that there is a dominant A–allele at the locus. With the help of this equations one can prove the so-called Hardy-Weinberg-law, namely the regularity that if there is no selective pressure, then these frequencies retain (cf. Schurz 2011, chpt.12.4): [222]

- $p_{n+1}(AA) = p_n(A)^2 = p_n(AA)$

- $p_{n+1}(Aa) = 2 \cdot p_n(A) \cdot p_n(a) = p_n(Aa)$

- $p_{n+1}(aa) = p_n(a)^2 = p_n(aa)$

Note that in these equations 'p' represents the reproduction and non-mutational variation (recombination) parameter of natural evolution: The frequency of AAs (homozygotic) in the nth generation is such and such. Via recombination it is possible that, e.g., two non-homozygotic brown-eyed parents (Aa and Aa) have a blue-eyed offspring (since meiosis is randomly and from the four possible recombinations AA, Aa, aA and aa only the last one results in a blue-eyed phenotype, the probability is one fourth).

Note also that this holds only within systems with reproduction and non-mutational variation (recombination), but neither selection nor mutation. Selection may be introduced into the dynamics with a parameter for selection. Let's assume, e.g., a selection pressure *s* on brown-eyed people (such a selective pressure could, e.g., be teh fact brought to the light by a Norwegian study according to which blue-eyed men significantly prefer blue-eyed women against brown-eyed ones; this phenomenon is sometimes explained with the fact that two blue-eyed parents (both *aa*) only can have a blue-eyed offspring and that therefore blue-eyed men have by such a choice a further indicator for fatherhood (cf. Laeng, Mathisen, and Johnsen 2007))—such a selection pressure is assumed, e.g., in table 2:

	Variation$_1$	Variation$_2$	Variation$_3$
Genotype (V_i)	AA	Aa	aa
Fitness (f)	$1 - s$	$1 - s$	1

Table 2: Implementation of a fitness factor for the selection of genotypes

Implementing a parameter for selection in the population dynamics changes the formulas above to the following one (here $k = 3$; (cf. Schurz 2011, chpt.12.5)), where the second coefficient is just a normalization of the parameter for selection—the higher the fitness of a variant, the higher the relative frequency of the variant in the offspring:

$$p_{n+1}(V_i) = p_n(V_i) \cdot \frac{f(V_i)}{\sum\limits_{j=1}^{k} p_n(V_j) \cdot f(V_j)}$$

Finally, to complete the evolutionary population dynamics one may implement the mutation of a variant V_i to another one V_j via a mutation coefficient m (frequency of V_i-mutations back or forth; (cf. Schurz 2011, chpt.13.1)):

$$p_{n+1}(V_i) = p_n(V_i) \cdot \frac{f(V_i)}{\sum\limits_{j=1}^{k} p_n(V_j) \cdot f(V_j)} \cdot (1 - m(V_i))$$

[223] So that's the formalization of the source domain of the gene-meme-analogy. But what about the target domain? As we have elaborated in the preceding section on the general form of the analogy, it's just a reinterpretation of the parameters and the variants for the cultural domain. We may express

this as follows:

$$p_{n+1}(V_i) = p_n(V_i) \cdot \frac{f(V_i)}{\overset{k}{\underset{j=1}{\Sigma}} p_n(V_j) \cdot f(V_j)} \cdot (1 - m(V_i))$$

$$\downarrow$$

$$p_{n^*+1}(V_i^*) = p_{n^*}(V_i^*) \cdot \frac{f^*(V_i^*)}{\overset{k}{\underset{j=1}{\Sigma}} p_{n^*}(V_j^*) \cdot f^*(V_j^*)} \cdot (1 - m^*(V_i^*))$$

Where $is(V_i) = V_i^*$, $is(n) = n^*$ etc. The reinterpretation runs as follows:

- n: ancestor relation n^*: generations/rounds

- m: mutation rate m^*: variation rate of information etc.

- f: natural selection pressure f^*: cultural selection pressure

- V_i: Genotypes V_i^*: Memes

12.3.3   Why the Diversity of Meanings of 'Meme' Fits into the Current Framework of Cultural Evolution

We have seen in section 12.3.1 that there is a quite diverse usage of the expression 'meme' within cultural evolutionary theory, but that cultural evolutionary theorists nevertheless share a core meaning of this concept as introduced via analogies, namely the property of being reproducible and adequately variable. In section 12.3.2 we have seen that the meme-concept (V^*) occurs within the analogy in three important contexts, namely within the context of the cultural reproduction and (recombinational) variation parameter $p_{n^*}(V^*)$, in the context of the cultural mutation parameter $m^*(V^*)$ and in the context of the cultural fitness-parameter $f^*(V^*)$. Since m^* and f^* are quite general, the only constraints of V^* (i.e. the meme-concept) as introduced by a partial contextual definition is to be a possible value of these functions which is to say nothing else then being something reproducible, variable and selectable. This thesis about the current constraints on a characterization of the meme-concept is not new:

> "[A] possibility is that such methods [that allow a clear character-
> ization of memes] will reveal that certain aspects of cultural trans-
> mission are not [classical]. Even in this case, however, evolution-
> ary models are still applicable [. . .]. Indeed, Darwin formulated his
> theory of evolution with little understanding of genes or Mendelian
> inheritance." (cf. Mesoudi, Whiten, and Laland 2006, p.344)

[224] And:

"Although the neuronal interpretation of the expression 'meme' seems to me plausible, the theory of cultural evolution doesn't hinge on it." (cf.: my translation of Schurz 2011, p.210)

Although the properties mentioned above which are the core of the meaning of the expression 'meme' are very general, in a more detailed characterization of the parameters of cultural evolution also the meme-concept may be clarified in a more informative way. Currently there are already some constraints for the fitness parameter of cultural evolution (f^*) formulated, but these constraints are also quite general:

- *Different kinds of fitness*: "Natural selection occurs when organisms differ in their *viability* and also when they differ in their *fertility*" (Sober 2000, p.57), whereupon under the 'fertility rate' the number of living born children of a parent and under the 'viability rate' the number of children reproducing themselves is understood. For memes a similar distinction should hold wherupon the memetican fertility rate may be understood as operationalizable via first citations in a citation index and the memetican viability rate may be understood as re-citations in a citation index.

- A meme is the more reproducible, the less cognitive dissonant it is with respect to main stream ideas (cf. Schurz 2011, p.230), (cf. Distin 2005, p.61) Cf. also Quine's web of belief where logic is at the core of our beliefs.

- One general selection criteria: The more a meme is organism self-defeating, the less fit it will be (cf. Schurz 2011, p.231).

- Complexity theory: Hierarchical structure of repeatedly nested sub-units increases the reproduction rate of so-called memplexes (cf. Distin 2005, p.41).

- Complexity theory: The more complex a system of memes, i.e. a memplex, is, the more unlikely it is that a meme/idea can be integrated. This is some kind of conservatism of complex systems (cf. Distin 2005, p.59).

- It's also possible to model frequency dependent fitness (selection parameter *s* includes also the frequency of a variant)

Although such constraints on a selection parameter for cultural evolution are quite general, more specific constraints out of, e.g., complexity theory seem to be available. By increasingly specifying these parameters also the meme-concept will be more specified. But there are also heavy dissimilarities regarding important properties of natural evolutionary theory:

- The concept of species turns into a concept of quasispecies in cultural evolutionary theory since there are no reproduction barriers for memes. So also a genealogy of memes or ideas fails in the classical sense.

- There is no meiosis going on in cultural evolution. For this reason recombinational variation must come into play differently.

- There is no unguided or undirected selection and variation in natural evolution. A consequence of directed selection is fast evolution. In general it holds that in natural evolution there is a mean variation and high selection rate whereas in cultural evolution there is a high variation and low selection rate

[225] To conclude our investigation of the gene-meme-analogy we can say that the currently diverse meanings of the expression 'meme' fit the requirements for this concept as introduced via analogies partially and contextually, but in order to turn the research programme of cultural evolution into a fruitful one, there seems to be a need of further analogical relations and specifications.

12.4   Conclusion

Our starting question concerned the fruitfulness of the theory of cultural evolution: How can meme theories of culture cope adequately with cultural diversity if there is disagreement about the meme-concept? We named three necessary conditions for a natural system to be a natural evolutionary system: reproduction, variation and selection. In cultural evolutionary theory analogue processes are assumed whereupon the cultural processes of reproduction, variation and selection are based on the replicator meme.

We have argued that, although memes are seen quite diversely as imitable entities, information contents, brain dispositions, brain software or so-called neuromemes, there seems to be a core meaning of the concept with the main relevant properties of reproducibility and adequate variability. Our detailed analysis of the main gene-meme-analogy shows that these different understandings of 'meme' share these main relevant properties of memes (V^*) to such a degree that they are acceptable for the present descriptions of cultural fitness (f^*) and variation/mutation (m^*) parameters. So, the partial understanding of the expression 'meme' is at least currently unproblematic. But of course this hinges on the generality of f^* and m^* and in order to turn the theory of cultural evolution into a fruitful research programme, it needs some further analogies and specifications.

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