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The Philosophy of Total Evidence and its Relevance for Phylogenetic Inference

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ABSTRACT

The test of congruence under total evidence as used in systematics has been tied to a Popperian philosophy of science, but is here shown to be related to the coherence theory of truth in metaphysics and thus to coherentism in epistemology. Since the test of congruence is coherentist, the contextual (theoretical) background of initial character conceptualization cannot be ignored as is suggested by some proponents of the total evidence approach. The relative merits of a total evidence approach versus conditional data set partitioning are considered, and whereas both have their merits and drawbacks, either approach requires causal grounding of character statements (statements of homology), at least approximately and defeasibly. The conclusion is that character congruence is a necessary, but not also a sufficient, condition for phylogeny reconstruction.

Keywords: Systematics, total evidence, test of congruence, Popper.

INTRODUCTION

At the heart of current debates concerning the theory and practice of systematics lie issues of probabilification of that science as they relate to the principle of total evidence. History as it unfolded and unfolds in the actual world is a unique process, and so is phylogeny: some authors find that for this reason, the probabilification of phylogeny reconstruction is inappropriate, as is the framing of hypotheses of phylogenetic relationships in probabilistic (likelihood) terms (Kluge, 2001). The involvement of probability in maximum likelihood analysis, as well as in Bayesian analysis of phylogeny is evident, but its involvement in cladistic parsimony analysis, in the principle of total evidence, and in the 'test of congruence' is less obvious. In this contribution I propose to clarify these issues by drawing a distinction that is often neglected in relevant discussions. This distinction concerns a 'metaphysical project', as opposed to an 'epistemological project' (also known as 'justification project': Kirkham, 2001). In its most simple form, this distinction requires that systematists separate what they believe history, or phylogeny, to be or to have been (i.e., a unique and irreversible process that occurs in the actual physical world outside mind and discourse), from what they believe to be justified or warranted to assert about this process and the world in which it plays out (a specific hypothesis of relationships).

This distinction also has practical implications for systematics. For example, proponents of total evidence have claimed that anything can be a potential character hypothesis as long as there is a rigorous method of testing such hypotheses: "There is no one operation for determining character states in this **system-it** can be *anything* that leads to the testable hypothesis of

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synapomorphy" (Kluge, 2003a: 356; emphasis added). The test that is believed to discriminate between these 'anythings' is that of congruence under parsimony, and total evidence is believed to increase the severity of the test (Kluge, 1997a, b, 2004). Griffiths (1999) put the issue in even more explicit terms, not from a (purportedly: Rieppel, 2003a) Popperian perspective, however, but from a probabilistic one: "Cladistic analysis can proceed from a list of *arbitrary measurements* by looking for congruence among the evolutionary trees produced by different measurements and thus 'bootstrapping' itself into a reliable character set" (Griffiths, 1999: 225; emphasis added). The belief is "that any historical signal present in the data will increase with the number of characters scored, and that this signal will override signals in the data present from other forces" (Naylor & Adams, 2003: 864; see also Rieppel & Kearney, 2002). Proponents of the total evidence approach identify a "disturbing trend towards data selectivity" (O'Leary *et al.*, 2003: 861), and cite Kluge (1997a) in support of the notion that inclusion of all data, including all "published data," results in a stronger test of phylogenetic relationships (O'Leary *et al.*, 2003: 862). In contrast, Naylor & Adams (2003: 864) identify "the total evidence" and the "'relevant evidence' schools of thought," where the latter asserts that "careful choice of characters is of primary importance." The central issue in such debates is about whether or not background theories (of inheritance, development, function, and evolution) should be brought to bear on character conceptualizations. At least some proponents of a total evidence approach eschew such theory-laden character conceptualization because of lack of positive knowledge (Kluge, 2003a; Grant & Kluge, 2004). But as Ruse (1988: 60) pointed out: "As soon as one starts breaking organisms into parts, one must bring in theory … Take two bears, one white and one brown. Do they differ in one feature, or does one take each hair separately … The point is whether someone who explicitly eschews the theory has the right to combine all the hairs into one feature." In fact, there cannot be any theory-free character conceptualization, just as there cannot be any theory-free observation (Popper, 1992; Hanson, 1961). To propose a putatively theory-free approach to character conceptualization, as with the famous punch-card approach to the automatic scanning of characters (Sneath & Sokal 1973, fig. 3-1), is not to eschew theory, but to take a specific theoretical stance instead, namely that the problem of homology can be dealt with by ignoring "details of structure" (Sneath & Sokal, 1973:87).

The Metaphysical and the Epistemic Projects

Metaphysics is the branch of philosophy concerned with issues of reality and being, i.e., it is concerned with the entities, their properties and their relations that may or may not exist in the 'real world out there'. In contrast, epistemology is the branch of philosophy concerned with the nature and extent of human knowledge, i.e., it is concerned with how we obtain knowledge, and how we can justify knowledge claims about the 'real world out there'. This is a much weaker claim about knowledge than that made by the metaphysical project.

In defense of the total evidence school of thought, Kluge (2004:206, emphasis added) raised metaphysical concerns: "Although epistemology may be what drives progress in science, the ontological status of what is being inferred cannot be ignored. Consider that monophyletic parts of phylogeny are *necessarily* unique … as is the character evidence that is used in the inference of such *things* … and whatever position is taken in discussions of epistemology, it must be consistent with that ontology." This statement seems confused, or confusing, at several levels.

First, the use of the expression '*necessarily* unique' invokes a modal context, i.e., the question whether the world could be in a different state from the actual one in which a process of phylogeny could have had different results from those in the actual world. Given the radical contingency of the evolutionary process (Kitcher, 1993), such could certainly be the case. To use Quine's (2001a) famous example: in our actual world, the expressions 'creatures with a heart' and 'creatures with kidneys' are co-extensive, i.e., they refer to the same set of organisms (which, for the purpose of this example, are the vertebrates). According to Kluge (2004), that 'part' of the phylogeny, i.e., Vertebrata, is necessarily unique. However, it is (logically) not impossible that the world could be in a state different from the actual one, in which evolution would have produced creatures with a heart but without kidneys, or vice versa (Lewis, 2002). The world might have been in a state where an evolutionary process would not have resulted in a taxon Vertebrata as we know it in the actual world, or it could be in a state in which no evolution occurs at all. Conversely, one may ask what it is that would make Vertebrata *necessarily* unique, i.e., what property would Vertebrata have to share necessarily relative to all possible world states? Properties such as having a heart or having kidneys will not do the work. The only property that Vertebrata share necessarily relative to all possible world states is a single common evolutionary (monophyletic) origin.

On that account, the common evolutionary origin becomes an *essential* property of Vertebrata, albeit an historical essence (LaPorte, 2004:176, n.4; 184, n.3; this is the so-called 'origin essentialism': Hanna & Harrison, 2004:280). This, however, is a metaphysical position that is quite different from the problem of how we *discover* a taxon Vertebrata, which is an epistemic question.

Second, Kluge (2004) stipulates a specific ontology, i.e., that parts of the phylogenetic nexus are particulars, as are the characters on the basis of which this phylogeny is inferred (Grant & Kluge, 2004), and then requests that epistemology follows this lead. But the thesis that taxa ('Vertebrata'), or homologues (the 'vertebrate heart'), are particulars (*'things'*) is certainly debatable (Rieppel, 2004a). Furthermore, ontological categories are not the kind of things we expect to bump into as we travel the world (Luntley, 1999:117). The idea that ontological commitments may flow from scientific theories has been argued by Quine (2001b; 'what is in the world is what is in our theories about the world': Gibson, 1982) and criticized by T.S. Kuhn (1974; see discussion in Rieppel, 2005). For Quine, a scientific theory makes ontological commitments to the extent that it specifies which objects must exist for the theory to be true. But a scientific theory is issued as a set of (theoretical) sentences, and Quine in particular insisted on the idea that there may be various ways in which to interpret sentences and their constituent parts. The result is an ontological relativism (Hylton, 2004), such that ontology is certainly the wrong place to start epistemology.

Third, Kluge (2004) fails to demonstrate how the 'total evidence approach' is epistemologically superior to the 'relevant evidence approach' in recovering the phylogeny, if taxa and homologues are conceptualized as particulars as he requests (see Mahner & Bunge, 1997, for a recent critique of 'bio-nominalism'). To fully understand the issues at stake in the discussion of the total evidence approach to phylogeny reconstruction it is important to clearly distinguish the metaphysical from the epistemological project, i.e., to distinguish words (that make claims about objects) from objects themselves. Organisms and their parts, fossil or extant, are objects (things, bodies, particulars): the heart of a guinea pig can be laid out on a dissection table, as can the femur of a *T. rex*. But a statement issued by a systematist, such as 'all vertebrates have a heart' is not an object. It is a sentence that expresses a proposition *about* objects and their parts. Systematists *talk about* characters, and code those in a data matrix. But the symbols that fill a data matrix are not objects. Instead, they stand for (are abbreviations of) sentences, i.e., character statements, and it is those character statements that issue propositions about objects (specimens) and their parts (see Rieppel, 2004b, for further discussion). To be true, false, or at least justifiable, these character statements must somehow relate to the objects that can be laid out on a dissection table. How such a relation is to be established, or justified, are issues discussed by metaphysicians and epistemologists.

The Coherence Theory of Truth

In the context of the metaphysical project, two classic theories of truth have been identified as age-old competitors (see the account in Kirkham, 2001), viz. the 'correspondence theory of truth' as opposed to the 'coherence theory of truth'. In the context of the epistemological project, the correspondence theory of truth translates into 'foundationalism', the coherence theory into 'coherentism' respectively. The correspondence theory of truth has traditionally been associated with a realist, the coherence theory with an idealist perspective.

Realism postulates a world outside mind and discourse. From a realist perspective, sentences have truth conditions, "which obtain independently of our recognition of their truth-values" (Dummett, 1981:451). The truth condition of a sentence is the condition the world must be in for a sentence about the world to be true or false. The truth-value of a sentence is its truth or falsity relative to the condition the world is in. To establish the truth-value of a sentence (it being true or false) in empirical science must rely on some sort of correspondence relation between what is said about the world of physical objects and that world. But words remain forever separated from objects by a logical (Körner, 1970), i.e., conceptual (Luntley, 1999) gap (see Rieppel, 2004b, for further discussion). This is why realist philosophers today request a *causal* grounding of words in the world of objects. It is the relation of hypothetical cause and observed effect that ties empirical theories to the physical world. This ultimately leads from the metaphysical notion of truth to the epistemic notion of justifiability.

In contrast, the coherence theory of truth is historically linked to idealism, which rejects correspondence relations between words and things as a condition for truth. Instead, the nature of truth consists in the coherence of a belief with a designated set of beliefs (where knowledge is defined as 'justified true belief'). In its most perfect, in fact ideal (Lynch, 2001), conception, a coherent system would be: i) comprehensive, i.e., account for all 'known facts' (incorporate the *total evidence* available), and ii) deductively inferential. In Blanshard's (2001:108) terms, "every proposition would be entailed by the others jointly, and even singly" in such a system, in which "the integration would be so complete that no part could be seen for what it was without seeing its relation to the whole, and the whole itself could be understood only through the contribution of every part" (Blanshard, 2001:108). Hennig (1966:129) adopted a coherence theory of truth: "That an assumption is true is shown by its 'confirmation' within the thought relationship, inasmuch as it not only does not contradict it but fits into it." Hennig (1950, 1966) based the integration of this system of thought on his principle of reciprocal illumination (see further discussion in Rieppel, 2003b).

As will be discussed in greater detail below, coherence is indeed a necessary condition for truth for both coherentists and foundationalists, but – according to the latter – not also a sufficient condition. Blanshard (2001:107), the most prominent early defender of the coherence theory of truth, recognized that the term 'coherence' may be used in a weaker, or stronger, sense. In the present context, the weak sense of coherence means simply consistency: a proposition coheres with a set of other propositions if it is consistent with all the other members of the set. The strong sense of coherence would be deductive entailment. For example, my belief that the streets will be wet tonight (Q) can be justified by its coherence with two other beliefs I hold (Sosa, 2000:137), i.e., that it is now raining (P), and that (everywhere and at all times) if it rains, then the streets get wet ($P \supset Q$). The relation of entailment is $[(P \supset Q), P \therefore Q]$, i.e., justification is by *modus ponens.*

To speak of coherence of character statements in modern systematics is to speak of their consistency (Kluge & Farris, 1969), i.e., to use coherence in its weak sense, not in the sense of deductive entailment (*contra* Kluge, 2003b).

The Concept of 'Total Evidence'

Introducing the concept of 'total evidence' in systematics, Kluge (1989) cited the relevant theoretical background, namely the work on inductive inference and its relevance for epistemology by the philosophers Rudolf Carnap and Carl Hempel. Consulting the references provided by Kluge (1989) of Carnap (1950) and Hempel (1965) shows that for these authors, the principle of 'total evidence' was tied to inductive inference, which is always probabilistic. Carnap (1995) and Hempel (2001) invoked 'logical' or 'inductive probability' (the two terms being synonymous: see Rieppel, 2003a, b, for a discussion) as a measure for the degree to which an inductive inference is implied by its premises (a sentence follows inductively from a premise if it is true under *some* of the conditions under which the premise is also true; logical probability can of course also be invoked in a deductive context). Logical probability thus translates into the (inductive) degree of confirmation of a hypothesis or theory, and that 'logical probability' had to be based on the total evidence available at the time. 'Total evidence' is thus a classic principle of inductive inference (e.g., Fitzhugh 1997; *contra* Kluge, 1997a, b, 2003a, b, 2004).

The empiricist philosopher Rudolf Carnap (see Carnap 1997a, b, for an accessible discussion) used 'total evidence' as a tool of decision-making, where the decision is to accept or reject a certain theory/hypothesis on inductive grounds. 'Total evidence' supports this process of decision-making by determining, in part, the value of a 'c-function,' which is the 'degree of confirmation' (synonymous with 'logical probability': see Rieppel 2003a; Lecointre & Deleporte 2004). At Carnap's hands, 'degree of confirmation' was also supposed to impact on a psychological function, which is the 'degree of credence' a subject is willing to bestow on a theory. So 'total evidence' also supports the process of decision making when it comes to the performance of an intentional *act* on the basis of the acceptance, or rejection, of a certain hypothesis/theory (e.g., building an aircraft on the basis of the theories of aerodynamics). This 'total evidence' for Carnap (1997b:972; emphasis added) comprised the *"total observational knowledge"* available to a person at the time of decision-making. That raises a number of issues (see further discussion in Rieppel, 2003b), most prominently the role of background knowledge (Lecointre & Deleporte, 2004) in establishing 'relevant' versus 'irrelevant' evidence (see the discussion in Haack, 1998), and in particular the discrepancy between the total evidence possessed at any given point in time, and the total evidence that could potentially be brought to bear on a hypothesis at some time in the future. If the gap between possessed evidence (total available evidence) and potential evidence (total evidence) cannot be estimated, then the logical probability and, with it, the degree of confirmation, will be compromised (Goodman, 2001). If this gap cannot be estimated, or closed, then why should we not stop research with the first piece of confirming evidence, why should we look for additional confirming evidence, and for how long should we do so to increase the degree of confirmation (logical probability) of a theory?

Early cladists emphasized 'uniquely shared derived characters', just as Hennig (1950) emphasized that a single synapomorphy may be good enough to support a hypothesis of monophyly. "'Hennig's Principle'" says that "the presence of a shared derived character allows to infer closest relationships – but it must be made clear that this is true only of those shared characters, which cannot be thought of as having evolved several times independently" (Schlee, 1971:12), Accordingly, and to give an example, Patterson (1973:235) concluded: "… there are several shared specializations of *Amia* and teleosts which are shown by the fossil record to have been acquired in parallel: some of these are unique, and therefore evidence of relationship, but others are more widespread." The point here made is that the *a priori* probability for a unique specialization to be evidence of kinship is greater than for characters that are more widely distributed. Only later did cladists shift towards maximizing the character evidence at the cost of (some degree of) homoplasy (Hennig, 1966; Farris, 1983; Kluge, 1989).

In systematics, the total evidence is the sum of all character statements available at the time. This includes, of course, not only new characters that result from continuing analysis, but also old characters that are part of the background knowledge. However, given different background knowledge, individual researchers may differ in what they accept as 'relevant' total evidence (Haack, 1998; for examples see Rieppel & Kearney, 2002). The total evidence confirms (supports), or disconfirms, hypotheses of relationships in terms of degrees of 'congruence', i.e., degrees of internal consistency, or coherence within and between sets and subsets of character statements. Systematists typically talk about 'congruent' characters, but what they really mean by that is the coherence of sets and subsets of character statements relative to an inclusive hierarchy (Patterson, 1982). More precisely: character statements predicate properties of organisms, such that coherence of sets and subsets of character statements translates into a congruent hierarchy of groups within groups. To the degree that the properties predicated by the character statements are natural ones (i.e., embedded in a process of cause and effect, such as inheritance from a common ancestor), the congruent hierarchy of groups within groups will also be a natural one (Rieppel, 2004a)

But coherence of sets and subsets of character statements typically comes in degrees, i.e., there typically are one or several character statements that conflict with the hierarchy of groups within groups marked out by those character statements that are coherent to the largest degree. But this means that hypotheses of relationships based on degrees of coherence of character statements will be more or less probable. A greater degree of coherence among character statements bestows a greater degree of probability on a hypothesis of monophyly (Rieppel, 1988:166).

Is the 'Test of Congruence' a Popperian Test?

Kluge (2004) acknowledged that Hempel (1965:64) used total evidence as the "basis for determining the degree of confirmation" of a theory/hypothesis, but he insisted on his "own logic" (Kluge, 2004:205), which he cast in terms of "justification" of, and "support" for, phylogenetic conclusions. Somewhat inconsistently, Kluge (2004) continued to insist that he (later) wedded the maxim of 'total evidence' to the Popperian concepts of 'explanatory power' (Farris, 1983), 'severity of test' and 'degree of corroboration.' I will here argue that such cannot be done without severe distortion of Popper's philosophy of science.

Kluge's (1997a, b, 2003a, b, 2004) adoption of a Popperian, i.e., 'falsificationist' approach to systematics is crucial for his claim that "there is no one operation for determining character states in this system-it can be *anything* that leads to the testable hypothesis of synapomorphy" (Kluge 2003a:356; emphasis added). This is a putatively theory-free approach to character conceptualization, which is patterned on Popper's idea that the *origin* of a theory/hypothesis is irrelevant as long as this theory/hypothesis can be tested, and potentially refuted. With this claim, Popper looked back on Kant, for he conceded coming close to Kant's conundrum (Popper, 1979:315). How could Kant dismiss the 'thing-in-itself' as an object of rational cognition, without some implicit knowledge of what this 'thing-in-itself' is? But Popper was not positing 'things' (Popper, 1988:116), he was positing theories, hypotheses, ideas. True, he wanted these theories to be applicable to 'things', but that says nothing about the 'things-in-themselves', it only says something about how well our theories perform in our *own* world of experience. As Kuhn (1974:2) put it: "… the aim is to invent theories that *explain* observed phenomena and to do so in terms of *real* objects, whatever the latter phrase may mean." In a similar sense, Kluge (2003a, b, 2004) can be interpreted to treat character statements as hypotheses the origin of which is irrelevant as long as they can be tested and potentially falsified. This argument will work only if the test invoked by Kluge is of a similar nature as the test invoked by Popper, however.

Popper (1983, 1989, 1992) is famous for having championed the hypothetico-deductive approach to scientific explanation. This requires that a testable prediction be deducible from a theory/hypothesis and its auxiliaries, but it fails to explain how we get a theory/hypothesis and its auxiliaries in the first place (Lipton, 2004). Even so, and according to Popper, if a prediction passes the test, the theory is corroborated; if it fails the test, the theory is falsified. In empirical sciences, predictions are usually issued in terms of observation statements, where observations may or may not have to be mediated by instruments. However, Popper's earliest claim to fame was his insight (Popper, 1979, 1992) that all observation statements are "soaked in theory" (Popper, 1989:387). For this reason, Popper had to take recourse to conventionalism, which emphasizes the importance of 'decision making' in science (compare Carnap's use of total evidence in support of such decision making). For Popper, therefore, it is the *acceptance* of an observation statement in a 'court of scientific opinion' (Popper, 1992) that results in the corroboration, or falsification, of a theory. It is for this reason that, according to Popper, a theory that has been accepted as being (logically) falsified needs not also to be rejected in practice (an argument exploited by Farris, 1983).

Given Popper's adherence to hypothetico-deductivism, the deduction of testable predictions from theory for him was the hallmark of 'THE scientific method', i.e., the criterion by which to demarcate science from metaphysics (for an account of the legend of 'THE scientific method' see Kitcher, 1993). With his falsifiability criterion, Popper found himself in opposition to those logical empiricists who championed a verifiability criterion by which to demarcate science from metaphysics. Verificationism also appeals to testing procedures (e.g., Friedman, 1999:150). According to Schlick (1959:86) for example, "it is simply impossible to give the meaning of any statement except by describing the fact which must exist if the statement is to be true. If it does not exist, then the statement is false." So the same fact can symmetrically confirm a statement (if it exists), or disconfirm a statement (if it does not exist). Popper turned this symmetry of confirmation and disconfirmation into an asymmetry of falsification. If a prediction deduced from theory is met by experience, it does not confirm the theory, it only corroborates it. If the prediction is not met, or rather, if it is accepted that the prediction is not met, falsification of the theory occurs. It is evident that no such asymmetry of falsification obtains in the 'test of congruence' based on total evidence. Congruent characters (coherent character statements) confirm a hypothesis of relationships to the degree that incongruent characters disconfirm it symmetrically. This is the relationship expressed in the ensemble consistency index (or tree length).

Kluge (2004) tied the use of total evidence in phylogeny reconstruction to Popper's concept of 'degree of corroboration'. But Popper's concept of corroboration is not one of confirmation. It does not make promises as to the future performance of a theory (Rieppel, 2003a). Degree of corroboration is merely an exhaustive list of the historical incidences of the number and kinds of tests a theory has passed. For David Hume, the future success of induction gains nothing form its past success: the mere fact that the sun has risen every morning ever since mankind populated the earth (and before) does not guarantee it's rising tomorrow (Popper invoked Russell's turkey, who after months of being well fed expected food on Christmas day when instead his head was cut off). In a similar sense, the future success of a theory gains nothing from its past corroboration. Instead, a dedicated Popperian will seek ways to falsify the most interesting theories, but these are also the most highly corroborated ones. In tying the concept of 'degree of corroboration' to phylogenetic analysis, Kluge (2004) did not raise the issue of the 'future performance' of phylogenetic hypotheses, but the question of the predictive (explanatory) power of such hypotheses is nevertheless an important one. To imply that phylogenetic hypotheses have no predictive power (which is not an implication made by Kluge, 2004) would mean to acknowledge that the *relative* empirical content (sensu Popper) of a hypothesis of relationships is zero (see Rieppel, 2003a).

Degree of corroboration increases with severity of test, another Popperian notion linked to the principle of total evidence by Kluge (2004). The severity of test, and with it the degree of corroboration, increases the riskier the prediction is that is put to test given the current background knowledge. In other words, the more a prediction transcends current background knowledge, the more severe is the test, and the higher the degree of corroboration if the prediction passes the test (Rieppel, 2003a). Cladists have contemplated Popper's concept of 'degree of corroboration in terms of his formula: C(*h, e, b*) = p(*e, hb*) – p(*e, b*). The term p(*e, hb*) is Fisher's likelihood function relativized to background knowledge, which expresses the probability a hypothesis *h* conveys on the evidence *e* given background knowledge *b*. But in the context of hypothetico-deductivism, *e* stands to *h* in the relation of logical entailment (Rieppel, 2003a), such that the likelihood of *e* comes out as 1 (Lipton, 2004). Popper's formalism can thus be re-written as C(*h, e, b*) = 1 – p(*e, b*), which means that the degree of corroboration increases with the improbability of *e* given the current background knowledge (Faith & Trueman, 2001).

Considerations about the degree of corroboration thus lead to the distinction of the prediction of data versus the accommodation of data by theory (Lipton, 2004). An inductivist will ask the question what degree of confirmation the total evidence available at the time will confer upon a theory/hypothesis? In light of this question it seems unimportant whether the evidence became available before, or only after the theory was formulated. Under Carnap's predicament, evidence was related to a hypothesis in terms of 'inductive', i.e., 'logical' probability, but such 'logical probability' cannot depend on the merely historical fact that data were or became available before or after the theory was proposed. This is in accordance with the total evidence approach in systematics, where severity of test (Kluge, 1997a) is said to increase if all available evidence, including the previously "published data" (O'Leary *et al.*, 2003:862), are included in the analysis. This means that the test of congruence under total evidence accommodates both old and new evidence.

Such a conclusion did not seem acceptable to Popper. For him, it was all too easy to formulate a theory that would accommodate previously available evidence. What he asked for (Popper, 1989) were bold, new predictions that significantly transcend the given background knowledge, putting the theory at its maximal possible risk. Significantly, Popper invoked 'total evidence' only in formulating his own positive solution, i.e., his own definition of 'degree of cornfirmation', and in that context he asked for a *subdivision* of total evidence: "That is to say, the *total evidence* e *is to be partitioned* into *y* and *z*, and *y* and *z* should be so chosen as to give *c(x, y, z)* the highest value possible for *x*, on the available total evidence" (Popper, 1997:222, n.82; see also Popper, 1989:288; and Rieppel, 2003a, for a discussion). In this context, *z* is the given background knowledge that includes old evidence, whereas *y* is the new evidence (the new observational results excluded from *z*: Popper, 1989:288), and *x* is the new explanatory hypothesis. According to Popper, it is the new evidence that confers the greatest degree of confirmation on a new explanatory hypothesis, not the old evidence relegated to background knowledge (for further analysis of this claim see Lipton, 2004). Systematists pursuing a total evidence approach evidently do not honor Popper's methodological requirement of subdividing the total evidence into old and new one.

Finally, there is the concept of the 'test' itself: the claim in a Popperian context that total evidence increases severity of test, and thus the degree of corroboration, in phylogeny reconstruction must be based on a notion of 'test' that is on par with Popper's. But such is not the case. Popper (1983) adopted a realist perspective, where "a correspondence theory of truth is the natural semantic side salad to a realist metaphysics" (Devitt & Sterelny 1999:252). Popper (1983:80) proclaimed "I believe in metaphysical realism," and hence concluded *"a statement is true if and only if it corresponds to the facts"* (Popper, 1973:46). But as explained above, words remain separated from objects by a logical (conceptual) gap, plus 'facts' are not objects, but rather complexes construed out of objects, their properties and their relations. What is required is a causal grounding of theories in the world of objects, such that prediction and test engage scientists in a causal (in Popper's case: experimental) interaction with the world of objects. This was, indeed, Popper's requirement: "… if you kick a rock hard enough, you will feel it can kick back" (Popper, 1988:116).

The test of congruence, whether or not under total evidence, does not engage the systematist in a causal interaction with the world of objects, however. Instead, it tests for logical relations between character statements, i.e., their coherence or lack thereof relative to a hierarchy. The test of congruence therefore is not a Popperian test, but is rooted in coherentism instead: "we test judgements by the amount of coherence which in that particular subject matter it seems reasonable to expect" (Blanshard, 2001:108). Because congruence tests logical relations between character statements only, not their causal grounding in the world of objects (in theories of inheritance, development, function, and evolution), it is not permissible to neglect the origin of character statements as Popper (mistakenly: Lipton, 2004) believed he could do with respect to theories that can be put to test in an experimental setup. Character statements are propositions about putative homology (primary homology statements sensu dePinna, 1991), but that requires that the shared characters are putatively tied into some causal process, such as inheritance from a common ancestor. Because the test of congruence does not address problems of causal grounding, *anything* (Kluge, 2003a) can indeed be subjected to it in search for some reasonable amount of congruence (coherence of character statements relative to a hierarchy), but the congruent system so obtained will remain 'hanging in the air.' Again, the argument is that coherence is a necessary condition of truth, but not a sufficient one also.

Griffiths' More Sophisticated Approach

According to Kluge (2003a), 'anything' can be a putative character, provided that there is a method that allows to test, and potentially refute, the corresponding character statements, where total evidence is said to increase the severity of test. However, the test of congruence tests for coherence and incoherence of character statements relative to a hierarchy only, yet coherence or incoherence of character statements are logical relations between sentences, not historical relations between organisms or their parts. This procedure therefore misses the requirement of causal grounding of character statements. As long as some degree of coherence is obtained, a hierarchy will result form the test of congruence. But without causal grounding of the character statements in theories of inheritance, development, and/or functional anatomy, no distinction seems possible between a natural, as opposed to an artificial hierarchy. Against this background, Griffiths' (1999:225; emphasis added) claim seems even more provocative: "cladistic analysis can proceed from a list of *arbitrary measurements* by looking for congruence among the evolutionary trees produced by different measurements and thus 'bootstrapping' itself into a reliable character set." Upon closer inspection, however, his claim is revealed to be more sophisticated instead.

As was done by Kluge (2003a), Griffiths (1999) again neglects the contextual background of character conceptualization in that he even admits 'arbitrary measurements' into phylogenetic analysis based on congruence. But he does not advocate a total evidence approach! Instead, he asks for congruence amongst cladograms obtained from different sets of such arbitrary measurements. The idea here is that if enough such measurements are involved, and if a high degree of congruence of trees obtains that result from different sets of such measurements, then such congruence of trees cannot be due to chance alone. According to Hempel (1965:146), a 'natural' classification is distinguished from an 'artificial' one by the fact that "those characteristics of the elements which serve as criteria of membership in a given class are associated, universally or with a high probability, with more or less extensive clusters of other characteristics." This is the criterion of coherence, which Whewell in 1840 applied to repeated patterns as follows: "The Maxim by which all Systems professing to be natural must be tested is this: – that the *arrangement obtained from one set of characters coincides with the arrangement obtained from another set*" (cited by Ruse, 1988:54; italics in the original). In cladistics, this procedure is known as 'taxonomic congruence', the classic competitor to the total evidence approach (see discussion in Rieppel & Grande, 1994).

What is believed to do the work in marking out a natural hierarchy based on taxonomic congruence is the "synergistic power of evidence" (Lipton, 2004:204), a principle that goes back to John Stuart Mill. Such an approach acknowledges that evidence is never certain, but stipulates that the confidence in the inferred phylogeny increases with an increasing number of characters partitioned into an increasing number of character sets that yield congruent trees. The arguments against the causal grounding of character statements capitalize on the fact that such causal grounding can never be certain (O'Leary *et al.*, 2003; see Rieppel & Kearney, 2002, for a discussion). For example, similarity of an ontogenetic trajectory can support a hypothesis of homology, but dissimilarity of ontogeny cannot refute a hypothesis of homology, for ontogenetic trajectories are themselves subject to evolutionary transformation. Griffiths' (1999) argument therefore emphasizes not a causal grounding of character statements, but congruence (or consilience) amongst trees resulting from different sets of character statements deployed in sufficient numbers: "consilience is like a quarrel or a tango. You must have at least two parties" (Ruse, 1987:239). "There are different ways of breaking organisms into groups," and if they coincide, "you are inclined to think that there's more than mere chance at work … Such coming together, could not be mere coincidence" (Ruse, 1987:238).

Griffiths (1999) argument is more sophisticated than the total evidence approach, and has something going for it in particular where molecular data are involved, whose alignment may involve some arbitrariness (alignment on the basis of parsimony as argued by Wheeler, 1998, chooses the conventional principle of simplicity as basis for alignment, a choice that is essentially arbitrary). Molecular data have the potential to come in large numbers, and their subdivision into different data sets may simply reflect the different genes sequenced. But beyond such pragmatic considerations, there remain well-known theoretical arguments against such a procedure: how many characters are enough, and what is the theoretical basis on which to subdivide characters into different data sets (see Rieppel & Grande,1994, for further discussion). Conditional data set partitioning seems superior to total evidence (simultaneous analysis: Nixon & Carpenter, 1996) in that is exploits the 'synergistic power of evidence' (Lecointre & Deleporte 2004; Rieppel, 2004b); it is inferior to total evidence in that it misses hidden support or conflict (Gatesy *et al.*, 1999). The best pragmatic solution therefore is to pursue both strategies (the 'global congruence' of Levasseur & Lapointe, 2001). Better still is to pursue both strategies in conjunction with an attempt to causally ground character statements, even if the latter can be achieved only partially, or defeasibly so (i.e., if it can go wrong).

Why the Causal Grounding of Character Statements is Important

In the context of the metaphysical project, a coherence theory of truth explains the nature of truth as the coherence relation within a most encompassing set of propositions (judgments, beliefs). In the context of the epistemological project, a knowledge claim (such as a claim about homology as indicator of phylogenetic relationships) is justified by its coherence with all or with a majority of other such claims. This is why coherentists tend towards holism, of which the total evidence approach is one aspect. On the coherence theory of truth, a proposition is true if it coheres with a designated set of other propositions. Such a theory must fail in the abstract, since "virtually any proposition can be fitted into some coherent set" (Walker, 2001:125). Walker (2001) objected to that criticism and pointed out that the coherence theory of truth pertains to beliefs that are actually and sincerely held, or would so be held under appropriate circumstances. But as Walker (2001) and others (Kirkham, 2001) noted, this only leads into an infinite regress. The truth that proposition *P* is actually held (or would be held under the appropriate circumstances) "consists in its own coherence with the system of beliefs. It cannot be a fact, independent of that system, that [*P*] is held. If it were, the truth that [*P*] is held would be a truth that did not consist in coherence" (Walker, 2001:147).

The same problem obtains for morphology based systematics in the context of the epistemic project, since if 'anything' can pass as a character (Kluge, 2003a), any character statement can in principle be made to cohere with any other character statements simply by its appropriate definition (Rieppel & Kearney, 2002). The same can apply to molecular sequence data if appropriate 'fudging' of alignment is permitted. As a consequence, the statement 'character statement *P* coheres with the designated set' can be true only if that very statement itself coheres with the designated set, such that "'character statement *P* coheres with the designated set' coheres with the designated set," etc. *ad infinitum* (Kirkham, 2001:115). The coherence theory of truth and with it epistemic coherentism therefore lead to an infinite regress, unless it is accepted that at some meta- (or meta-meta-meta- etc.) level a proposition (belief, judgment) is accepted to be true by coherence with a mind-independent fact (Kirkham, 2001:115), at which point we "would no longer have a pure coherence theory of truth" (Walker, 2001:147). This explains the initial implausibility of the coherence theory as a metaphysical project if perceived from the perspective of empirical science, for it is intuitively implausible that truth should obtain from the mere relation of coherence between truth-bearers (such as propositions), as opposed to their relation to the world (Kirkham, 2001:111).

As noted by Kirkham (2001:104), "many defenders of coherence theory, if they were made aware of the distinction, … would identify the justification [i.e., epistemological] project as the one they intend their theories to satisfy." Systematists are well aware that coherence of character statements is almost universally imperfect. Character statements will generally not come out as fully coherent relative to a hierarchy; there generally will be at least some degree of inconsistency or incoherence (incongruence, homoplasy). However, if there are two sets of propositions (e.g., two sets of character statements) that are coherent within themselves, but incoherent between themselves, then coherence alone cannot offer any criterion of choice between these sets of beliefs or propositions in terms of how well they approximate the world of objects, their natural properties and their causal relations. If two sets of data that are congruent within but incongruent between them mark out different hierarchies of the same organisms, then they will be seen to support two different hypotheses of phylogeny. Again, congruence (coherence of character statements) alone cannot offer a criterion of choice between these two hierarchies in terms of their naturalness. The only way to resolve the conflict seems to be to put the two data sets together in a simultaneous analysis (Nixon & Carpenter, 1996), i.e., to apply the principle of total evidence (Kluge, 1989). This is why the ideal system built on coherence will take into account all 'known facts', i.e., the total evidence available (Lynch, 2001:99). In sum, to test for character congruence (coherence of character statements) is a *necessary* condition for systematics, but it is not also a *sufficient* condition. Just as Popper will have to concede to coherentism that the theory and the appropriate test statement must cohere if any relevant testing is to occur (Audi, 2003), it has to be acknowledged that incoherent talk about the world does not make much sense, not in systematics, nor in any other domain of discourse. But beyond that, empirical science requires that its theories and explanations be well aligned with the causal structure of the world (Boyd, 1999).

It is important to realize that incoherence (incongruence) can undermine a particular knowledge claim, such as a particular (preferred) hypothesis of relationships, but that this does not mean that mere coherence suffices to justify a particular knowledge claim (Audi, 2003:204). This is essentially the insight of Farris (1983; see also Kluge, 2001, 2003a, b) who claimed that incongruence can undermine cladograms (the falsificationist program), but that congruence does not support a phylogenetic hypothesis, for the congruent characters need not be homologous, they could also be homoplastic (parallel; but see Wilkinson, 1991). One can think of the sum of all characters over the sum of all taxa relative to the finite number of possible hypotheses of relationships given the finite number of terminal taxa as the total explanatory space of the evidence at hand. Farris' (1983) claim for increased explanatory power is not based on the claim that parsimony maximizes the number of character statements that can be explained as homologies. This would mean to use the coherence of character statements as a guide to a positive (even though provisional, defeasible, and probabilistic) knowledge claim such as the one put forward by Nixon & Carpenter (1996:237, emphasis added): "Simultaneous analysis … produces the *best-supported* hypotheses…" On Farris' argument, explanatory power increases by minimizing the number of *ad hoc* hypotheses of homoplasy (within the total explanatory space), not by maximizing hypotheses of homology. Coherence of character statements cannot support, but incoherence can undermine, hypotheses of phylogeny. Taken to its logical conclusion, Farris' (1983) arguments remain agnostic about the hypothesis of relationships that is compatible with maximal coherence of character statements. "Farris' argument … is basically concerned to point out what parsimonious cladograms do *not* say" (Sober, 1985:213), or, in other words, Farris' (1983) argument is concerned with homoplasy, not with homology (Wiesemüller *et al.*, 2002). The concern is with the 'least falsified' not with the 'best supported' hypothesis of relationships. But that argument lacks Popper's asymmetry of falsification (Rieppel, 2004c), for the flip side of Farris' (1993) argument is to say that maximal coherence of character statements provides support for hypotheses of relationships (Nixon & Carpenter, 1996), as Farris (1983:11) himself pointed out: "… the decision [the choice amongst competing hypotheses of relationships] is made by accepting the stronger body of evidence over the weaker, and *ad hoc* hypotheses of homoplasy are required to the extent that evidence must be dismissed in order to *defend* the conclusion."

CONCLUSIONS

At the end of the day, Carnap (cited in Chisholm, 2000:111) conceded "those logical empiricists who were attracted to the coherence theory of truth tended to lose sight of the … confrontation of a statement with observation". Coherent systems of beliefs need to be anchored in the world of experience, if they are to contribute to the justification of empirical knowledge claims. Coherent systems of character statements need to be anchored in the relevant causal relations of the physical world, if they are to contribute to the justification for finding one hypothesis of relationships more likely than another one. The causal grounding of character statements might be direct (through the 'evo-devo' research program: Wagner, 2001), or indirect, such as through homology criteria for morphology (believed to be defeasibly rooted in causal relations of inheritance and ontogeny at least to some degree: Rieppel & Kearney, 2002). The classical criteria of homology (Remane, 1952) are those of topology and connectivity, and their rooting in ontogeny results from the fact that due to causes of inheritance, 'developmental modules' "occupy specific physical sites within the embryo" and "exhibit varying degrees of connectivity to other modules within the embryo" (Raff & Sly, 2000:102). In molecular systematics, secondary structure may provide guidance for the alignment of mitochondrial gene sequences (e.g., Kjer, 1995; Mindell *et al.*, 1997; Olson & Yoder, 2002). A moderate foundationalism is required to make empirical sciences work, one where the rooting of coherent systems of propositions is not deductive, but probabilistic, and therefore defeasible (Audi, 2003:213).

The positivist philosopher Otto Neurath pictured coherentism in a famous metaphor: he compared empirical science to a raft that over time has to be rebuilt plank by plank while it is out at sea. For systematics this means that character statements may need to be revised one by one while being put to work in phylogeny reconstruction. Neurath's metaphor relates to a holistic view of science known as the 'Duhem-Quine-thesis': the web of scientific knowledge is a web of coherent statements. According to Quine (2001a), any one of these statements may at any time be found to require revision, yet that revision will have to take place without disruption of the whole web. The important thing to realize, however, is that the impulse for such revision itself will not be generated by mere incoherence, but by the failure at the margin of that web of statements to attach to the world of physical objects, their natural (i.e., causally efficacious) properties and causal relations. Statements near the center of the web of scientific knowledge tend to include theoretical terms (that stand for unobservables), such that coherence is of prime importance for their justification, but the confrontation with the world becomes increasingly more important as one approaches the margins of the web. It is at the edge of the web of scientific knowledge where Quine (2000:290) finds science to "line up for inspection," i.e., to measure up "to the perceptual network of similarity" (see Dummett, 1993, for a more sophisticated interpretation of the metaphor).

In systematic biology, statements of homology are theoretical statements on unobservables, for we cannot observe similarity 'due to common ancestry' (Rieppel, 1992, 2004b). Coherence, therefore, is of prime importance for statements of homology. But character statements that may or may not turn out as statements of homology must not only cohere in support of a phylogenetic hypothesis, they must also be approximately aligned with causal relations (Boyd, 1999) that underlie biological structure. This is perceptually achieved by the use of established criteria of homology (Rieppel & Kearney, 2002), and causally by heredity and developmental biology in its broadest sense.

RESUMO

O teste de congruência baseado em evidência total, como é usado na sistemática, foi atrelado à filosofia Popperiana de ciência, mas aqui se demonstra estar relacionado à teoria coerentista da verdade na metafísica e a teoria do coerentismo na epistemologia. Como o teste de congruência é coerentista, a base contextual (teórica) da conceitualização inicial de caracteres não pode ser ignorada como sugerido por alguns proponentes da abordagem de evidência total. Os méritos relativos apresentados pelas abordagens de evidência total e de partição condicional do conjunto de dados são considerados. Apesar das duas abordagens apresentarem seus méritos e desvantagens, ambas necessitam de um embasamento causal para definição dos caracteres (definição de homologia), ao menos de forma aproximada e falseável. A conclusão é que a congruência de caracteres representa uma condição necessária, mas não suficiente para a reconstrução filogenética.

PALAVRAS-CHAVE: Sistemática, evidencia total, teste de congruência, Popper.

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