INTRODUCTION

From our vantage at the end of the 20th century it is possible to trace an evolution in the use of the word ‘knowledge’, a journey from the absolute to the relative. This paper sketches the main steps in this evolution and describes a notion of information template, in terms of which the beliefs of an agent may be ordered in a spectrum ranging from those to which the agent attaches the greatest weight (and which fulfil the operational role of knowledge) to those the agent is readily willing to retract.

Our perspective is a logical one, and more broadly a scientific one. No apology for this is necessary. The chief advances in philosophy during the past century have occurred in logic and the philosophy of science. Indeed, much of postmodernism is merely a distorted reflection of ideas that have contributed usefully to the development of logic and science. We resist the temptation to deliver yet another critique (Kimball 1990; Gallo 1991; Holton 1993; Gross & Levitt 1994; Sokal & Bricmont 1998) of the intellectual frivolity perpetrated by French philosophers during this century (and the humourless mangling of their jocund absurdities by sanctimonious epigones), choosing a more constructive goal. By giving due prominence to semantic issues, we draw together apparently disparate strands from modal logic, information theory, and non-monotonic logic. The unifying framework that results embodies the current agent-oriented paradigm in logic, from which information templates emerge naturally.

MILESTONES IN THE JOURNEY FROM KNOWLEDGE TO BELIEF

At the start of the 20th century, Bertrand Russell inherited from Gottlob Frege the notion of a formal system and a mature quantification theory. Implicit in Russell’s approach was the assumption that logic is about ‘the’
universe of mathematical and physical objects and that well-formed sentences have significance (meaning) to the extent that they report on facts or beliefs about this universe (Russell 1940:168-172). To fearlessly oversimplify, there was assumed to be just one way to assign denotations of constants and hence meaning to the sentences of a formal system. In terms of this logical atomist paradigm, it made sense to speak of a sentence as being true without qualifying the description by making explicit the universe of discourse and the denotations in it relative to which truth obtains. And it therefore made sense to claim, as Russell famously did, that 'Quadruplicity drinks procrastination' has no meaning.

This approach did not long survive the rise of model theory following Tarski's publications on truth and logical consequence (Tarski 1956). For an array of reasons that deserve, but cannot here be granted, extended treatment, the model-theoretic paradigm supplanted the logical atomist paradigm. Truth came to be seen in terms of a relation between a sentence and an interpretation of the language. An interpretation is a set-theoretic structure, and the relation determining the assignment of truth values is established by specifying the denotations of terms and predicates in the domain of the interpretation (Enderton 1972; Bell & Slomson 1969). Under the model-theoretic paradigm, there is no difficulty at all in giving a meaning to 'Quadruplicity drinks procrastination', for it is necessary only to select a set-theoretic structure and assign denotations to the terms 'Quadruplicity' and 'procrastination' and to the predicate 'drinks'. Whether the resulting interpretation turns out to be useful is another matter entirely.

The new paradigm helped undermine the connotation of absoluteness carried by the word 'knowledge'. A tradition traceable back to Plato (Schmitt 1992; Laux & Wansing 1995) holds that knowledge is justified true belief. For an unqualified 'true', it now became prudent to substitute reference to the interpretations relative to which truth obtained. The journey towards relativity was carried further by difficulties surrounding the notion of justification, several of which are pointed out by Musgrave (1999).

If we take a sentence to be (conclusively) justified whenever it is entailed by some sentence that is true (in all the interpretations deemed to be of
relevance), then all sentences that are true (in the relevant class of interpretations) are justified, and so too are all the logically weaker statements entailed by them. This is problematic on two accounts. Not only does it require the agent whose belief is thus justified to be logically omniscient, but now 'true' has subsumed 'justified', a subsumption that is undesirable because two agents may both believe a true statement, but one may be 'justified', in some intuitive sense, in believing it, while the other agent may not. Thus the notion of justification should not only involve some added value beyond truth but should be a relative concept taking an agent as a parameter and subject to resource bounds in the agent.

In the justified-true-belief view of knowledge, belief is of interest only as a germ from which knowledge may spring. What if only partially justified beliefs could spring from the germ? Consider scientific reasoning. During the 1930s Popper's revival of Hume's demolition of induction as a source of knowledge (Popper 1959) interacted with contemporaneous developments in probability and statistics to bring about Carnap's logical reconstruction of probability theory (Carnap 1950). A long controversy ensued between Popper and Carnap (and their adherents) over such questions as whether Carnap's explication of degree of confirmation was supposed to (or could possibly) be an adequate measure of the acceptability of scientific theories, and whether probabilistic support qualified to be regarded as inductive support (Carnap 1953; Popper 1954; Bar-Hillel 1955a; Popper 1955; Bar-Hillel 1956; Carnap 1960; Carnap 1962; Popper & Miller 1983; Levi 1984; Jeffrey 1984; Good 1984; Popper & Miller 1984; Redhead 1985; Gillies 1986; Eells 1988; Dorn 1991). Two insights emerged almost in passing from the sustained scrutiny to which scientific reasoning was subjected.

Firstly, there is general acceptance that scientific reasoning is defeasible. Suppose that one were to adopt a conjecture because, in the light of evidence, it is more probable than some competitor (say, its negation). Then this would be only a tentative adoption, for it might be necessary to retract the conjecture in the light of new evidence relative to which its probability is less (the new evidence thus undermining or defeating the conjecture). Indeed, it might be necessary to revise the whole probability measure
underpinning the initial inference (the key idea of Bayesian inference (Howson & Urbach 1989)). However one may view the role of testing in distinguishing between theories, scientific 'knowledge' occupies a middle ground. A scientific theory is a set of beliefs judged reliable because they have survived a process of testing, but this reliability does not possess the mystical absoluteness that is one connotation of the word 'knowledge' and that used to perfuse reference to 'the laws of nature'.

Secondly, it has come to be seen that the naive view of induction, as a process by which instances (such as observations of black ravens) partially justify a universally quantified sentence (such as 'All ravens are black'), is mistaken. This insight is due not only to Hempel's paradox (which asserts that observation of any non-black non-raven would have to count as a confirming instance of the generalisation) and Goodman's paradox (which asserts that a given instance can be regarded as confirming a range of different generalisations (Goodman 1965)), but also to a growing perception that probability constitutes merely one of many mechanisms capable of supporting defeasible conjectures. In terms of the class of alternatives known as non-monotonic logics, the sentence 'All ravens are black' of the object language would not be the vehicle used to reflect a preponderance of black ravens in the world. Instead, a default rule would be used to represent this information, and such default rules would appear either as special-purpose rules of inference (in the default logic of Reiter (Reiter 1980)), or as semantic orderings in logics based on minimal model semantics (which we shall examine in detail later). Whatever the mechanism of formalisation, the formation of defeasible beliefs could no longer be straitjacketed into a pattern of instances confirming a universal generalisation.

If the analysis of scientific reasoning drew attention to the idea of defeasibility and the inadequacy of naive induction, then the final step in construing belief as the concept of primary utility had its origin in the advent of the computer during the 1940s and Turing's 1950 paper (Turing 1950) on the possibility of machine intelligence. Discussions of scientific reasoning were concerned only with human agents, and there have never been lacking those willing to endow humans with special epistemic powers,
from Plato to Penrose (Penrose 1989; 1994). Thus the defeasibility of scientific reasoning could be interpreted as a necessity imposed by a restrictive methodology. However, the new fields of artificial intelligence and cognitive science found it natural to adopt an agent-oriented stance which broadened the range of application of such concepts as rationality beyond merely human agents.

What is an agent? Pollock (1995) memorably contrasts agents and rocks. Each is a stable structure in a dynamically changing world. But whereas a rock achieves its stability passively, by virtue of being hard to destroy, an agent achieves its stability by interacting with its surroundings in order to render these more congenial to continued survival. Whether animal, vegetable, or mineral, a rational agent is one which has beliefs reflecting the state of its environment and constraining its actions. As for the source of these beliefs, experience in building robots shows that knowledge, in any absolute sense, is unobtainable even by observation. Sensory input requires disambiguation. For instance, the two-dimensional image upon the retina of an agent may in principle be the projection of an infinite number of different three-dimensional configurations in the field of vision (Marr 1982; Pinker 1997), and the agent will defeasibly have to choose between these explanations (although the mechanism of choice is typically unconscious and performed by a specialised module). Even at the conscious level, common-sense reasoning goes far beyond the constraints of valid inference while maintaining a greater or lesser degree of plausibility. It is not merely scientific reasoning that is defeasible; defeasibility is ubiquitous.

AN ILLUSTRATIVE APPLICATION

In the sections that follow, we shall repeatedly refer to the following example. Consider an agent observing a simple fan-heater system (FHS). The FHS has just two components: a fan and a heater. (Lest the system appears wholly trivial, reflect that it is a coarse-grained view of a nuclear powerplant in which the heater symbolises the pile and the fan the cooling system.) Of interest to the agent is the state of the system, and the state of the system is determined by two elementary facts: whether the fan is on, and whether the heater is on. The agent represents his beliefs about the
system in a propositional language with two atoms: $p$ represents the fact that in English would be expressed by 'The fan is on' and $q$ the fact expressed in English by 'The heater is on'. The propositional language is equipped with the standard connectives such as $\neg$ for 'it is not the case that', $\wedge$ for 'and', and $\lor$ for 'either $p$ or $q$ or both'.

The FHS may at any time be in one of four states. Each state may conveniently be treated as a vector of two co-ordinates. According as $p$ is true or not, the first co-ordinate is either 1 or 0, and similarly the second co-ordinate is 1 if $q$ is true, 0 otherwise. Thus 11 is the state in which both the fan and the heater are on, 10 the state in which the fan is on but the heater is off, 01 the state in which only the heater is on, and 00 the state in which both are off.

The agent wishes to answer, with the aid of observations of the system, the question 'What is the current state of the system?' The fanciful reader may imagine that the system is really a nuclear powerplant and therefore potentially dangerous. The agent sits in the control room and has the responsibility, should the system enter a state which may lead to meltdown or some other disaster, of averting calamity by pulling a large red lever, which shuts down the system. Ideally, the agent would have complete information about the state of the system, perhaps by being equipped with sensors enabling it to observe clearly both the fan and the heater. However, the interesting cases are those in which the agent has incomplete information.

THE PROBLEM OF INCOMPLETE INFORMATION

As Davis (1990) demonstrates, everyday life requires us to cope with partial information. One believes that the water in the tea-kettle will come to a boil soon after one presses the switch, but does not know how soon, or in fact whether all the preconditions for boiling are satisfied (is the kettle in good working order?).

This incompleteness cannot be overcome by trying harder. Every agent has limited resources. In particular every agent has a limited sensory apparatus,
and as in the case of vision must disambiguate input by selecting from amongst a large collection of external circumstances that would produce the same sensory input. Furthermore, the preconditions that have to be satisfied in order for the water to boil (or one's car to start or indeed for any action to bring about the intended effect) may be multiplied endlessly. Should one wish to check in the newspaper how one's investments in the stock market are doing, it is not even feasible to enumerate, let alone to check the satisfaction of, preconditions such as that the vendor is willing to sell one a paper, that the newspaper is in a language one understands, that there is sufficient light to read it by, that no lunatic passerby will tear the paper from one's hands, that the newspaper is not a fake distributed so as to spread disinformation, that the editor has not decided to stop printing stock prices, that one will not suffer an hallucination instead of actually reading the paper. The infeasibility of enumerating and checking preconditions is known in artificial intelligence as the qualification problem, and it is merely one amongst a number of similar problems like the frame problem (Brown 1987; Pylyshyn 1987).

One copes with incomplete information by invoking some mechanism for the formation of defeasible beliefs. Such a mechanism may apply a default rule (a rule having general but not universal validity). Default rules are sometimes founded on judgements of relative frequency (quantitative in the case of probability theory but quite likely to be qualitative in other contexts). Of this kind would be a rule cautioning that to enter a lottery is to lose your investment because of the very small chance of winning. But default rules may be founded on a notion of typicality (or normality): the psychologists Kahneman and Tversky have shown that ordinary reasoning often violates the principles of probability theory and seems instead to have recourse to stereotypes (Kahneman, Slovic & Tversky 1982).

These considerations raise several questions for the logician. How can one measure the information available to an agent? How can one represent constraints on an agent's sensory apparatus (or more general resource bounds) that may compel it to operate with incomplete information? How can one implement mechanisms for the formation of defeasible beliefs? One strand in the progress of logic during the 20th century is tied to precisely
these questions, and its course is traced in the next three sections, which deal respectively with semantic information theory (Carnap & Bar-Hillel 1952; Hintikka 1968; Hintikka 1970a; Hintikka 1970b); modal logic; and non-monotonic logic (McCarthy 1980; McCarthy 1986; Shoham 1987; Krauss, Lehmann & Magidor 1990; Lehmann & Magidor 1992).

THEORIES OF INFORMATION

How can one measure the information available to an agent? The term information is usually assumed satisfactorily to have been explicated by Hartley (1928) and Shannon (Shannon & Weaver 1975) in the context of the transmission of messages, for instance over a telephone line. Shannon himself was aware that the informal use of the term was not fully captured by Hartley's explication and cautioned: 'Frequently the messages have meaning. These semantic aspects of communication are irrelevant to the engineering problem.' Information is of course associated with the elimination of uncertainty, but two kinds of uncertainty may be involved. There is the unexpectedness of the choice of a particular formulation of a message, and there is the unexpectedness of the events reported by the message. Under very special circumstances there may be an isomorphism between the two, as when each relevant event is represented by an unique string of symbols, but in general, languages rich enough to describe non-trivial systems will contain multiple strings that are semantically equivalent, so that the same event may be represented by two or more strings of which one is perhaps a more conventional or ordinary usage than another.

That the Hartley-Shannon definition addresses the uncertainty of formulation rather than the uncertainty of event, may be seen as follows. Suppose that a communication channel is able to transmit $n$ messages (each message being some string of symbols from a given alphabet). Assume, for simplicity, that each of the messages is equally likely to be selected by a sender, so that each message $s$ has a probability $p(s) = 1/n$ of being chosen. Motivated by a desire 'to set up a quantitative measure whereby the capacities of various systems to transmit information may be compared', Hartley defined the amount of information produced when a message $s$ is
selected from $n$ equally likely messages to be $\log l/p(s)$. Since $l/p(s) = n$, the connection with the capacity of the system is clear. Use of the logarithm is inessential; it merely confers the benefit that, as Shannon puts it: 'Parameters of engineering importance such as time, bandwidth, number of relays, etc., tend to vary linearly with the logarithm of the number of possibilities.'

From the formula it is apparent that the Hartley-Shannon definition relies on the relative frequencies of occurrence of symbols rather than on the meanings of messages, and therefore would ascribe a greater information content to an unexpected formulation. For example, the string of symbols 'A rotating sphere of compressed silicaceous material accumulates no accretion of bryophytic vegetation' would be adjudged to have greater information content than 'A rolling stone gathers no moss', merely because the former is in practice uttered less frequently. While the emphasis on relative frequency of symbols is useful for many important purposes such as error-detection and correction, it is a doubtful principle on which to base an explication of information.

An account of the mismatch between symbol-frequency and event-frequency was first set out by Bar-Hillel (1955b), who went on (with Carnap) to formulate a theory of semantic information (Carnap & Bar-Hillel 1952). Semantic information theory focuses on the elimination not of the uncertainty pertaining to the choice of message but that related to the question 'What is the state of the world?' As suggested by Popper (1959), the more information we have about a system, the more states we are able to rule out. Thus the intuition underlying semantic information theory is model-theoretic: the set of possible states of the world (or of some system) is partitioned into two blocks consisting firstly of those states that, as far as is known, remain possible candidates for being the actual state of the world, and secondly those states that may be excluded from consideration. (The special case of no information corresponds not to a genuine partition but to a pair consisting of the set of all states, these being viewed as possible, and the empty set of states, these being the excluded states.)
This may be illustrated by the FHS. Suppose the agent observing the system is equipped with a sound sensor only, and so can detect whether the fan is on but not whether the heater is on. If the actual state is 11, the information available to the agent may be represented by the partition that follows, in which the lower block comprises the possible candidates and the upper block the states that the agent is able to rule out:

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Strictly speaking, we have here not merely a partition but an ordered partition: to encode the idea that one block contains excluded states and the other not, we have adopted a convention which positions the excluded states above the remainder.

This dichotomous ordered partition (which orders the states by assigning them to one of two levels) is a local representation of the agent's information, in the sense that the state of the FHS may change and a new ordered partition be appropriate. For example, suppose that the actual state changes from 11 to 01, by virtue of the fan switching off. Given the agent able to hear the fan but not feel the heater, a suitable representation of the available information in the new state would be given by the ordered partition

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We shall see in the next section how epistemic logic links together the local representations of an agent's information into a global representation.

The semantic information represented by a dichotomous ordered partition of states may be expressed sententially by exploiting the finiteness of the system. Every state has a corresponding state description in the appropriate
propositional language; a state description is a conjunction in which every atom appears exactly once and is either negated or unnegated. The significance is that a state description is true in exactly one state, namely that which it describes. For example, the state 10 of the FHS has the state description \( p \land \neg q \). Now exclusion of a state may be indicated by negating its state description. The result is a sentence (called a *content element*) falsified only by the relevant state and equivalent to a disjunction in which every atom appears once, negated or unnegated. Every sentence is equivalent to a set (conjunction) of content elements and every dichotomous ordered partition of states may therefore be represented by the sentence whose content elements correspond to the excluded states. (Equivalently, by the logically strongest sentence true in the bottom states.)

Summarising, semantic information theory model-theoretically represents the information available to an agent as a dichotomous ordered partition of states, and can also represent this information sententially via a correspondence between content elements and excluded states.

**EPISTEMIC LOGIC**

How can one represent constraints on an agent's sensory apparatus (or more general resource bounds) that may compel it to operate with incomplete information? The possible world semantics of epistemic logic gives one method.

Epistemic logic uses a *modal* language to express sententially the information available to an agent, and does so for two reasons. Firstly, by extending the simple propositional language of the previous section so as to include a modal operator \( \Box \), and by defining the semantics in such a manner that \( \Box \alpha \) expresses 'According to the information available to the agent, \( \alpha \) is the case', it becomes possible to distinguish the agent's perhaps limited information from the information that an omniscient oracle would have. (In the case of multiple agents, include multiple operators \([1],[2],..., [n]\) indexed by identifiers for the agents.) Secondly, it becomes possible to represent information acquired by introspection or the beliefs one agent may have about other agents' beliefs.
For our purposes, the use of modal operators is less pertinent than the possible world semantics itself. A set of possible worlds (for our purposes, these may be taken to be the states of a system like FHS) is structured by a binary accessibility relation (Chellas 1980). The accessibility relation encodes the constraints which limit the agent's access to facts about the system. For example, in the case of an agent observing the FHS and able to hear the fan but not detect whether the heater is on, the set of possible worlds would be \( W = \{11, 10, 01, 00\} \) and the appropriate accessibility relation

\[
R = \{(11, 11), (11, 10), (10, 11), (10, 10), (00, 00), (00, 01), (01, 00), (01, 01)\},
\]

which is clearly an equivalence relation having as its equivalence classes the blocks \( \{11, 10\} \) and \( \{01, 00\} \) respectively. The former consists of the states regarded as possible candidates when the system is actually in state 11 (or in 10), and thus conveys the same information as the ordered partition

\[
\begin{array}{c|c|c}
01 & 00 \\
\hline
11 & 10
\end{array}
\]

previously did. The second equivalence class, namely \( \{01, 00\} \), consists of the states regarded as possible candidates when the system is actually in state 01 (or 00), and is equivalent to the ordered partition

\[
\begin{array}{c|c|c}
11 & 10 \\
\hline
01 & 00
\end{array}
\]

Recalling that these ordered partitions could be viewed as local model-theoretic representations of the information available to the agent, it follows that the accessibility relation may be viewed as a global model-theoretic representation. When the system is in a state \( w \), the accessibility relation gives an equivalence class of states each of which is, because of the limitations to which the agent is subject, indistinguishable from \( w \) and hence also regarded as a possible candidate to be the actual state. This
equivalence class suffices to determine a dichotomous ordered partition. (The extreme case of complete information would be encoded by an accessibility relation which is the identity relation on the set of possible worlds.)

The sentential representation of the information available to the agent is governed by the accessibility relation according to the following truth definition: a sentence □α is true at a state w if α is true at every state in the equivalence class of w. The set of sentences of the form □α that are true at w constitutes the sentential expression of the information available to the agent when the system is actually in state w, and it is customary to speak of the sentences α as the knowledge or more generally the beliefs of the agent. (There is a tradition according to which the term 'knowledge' is used when the accessibility relation is an equivalence relation and 'belief' is used if the criteria are relaxed, but this is not relevant for our purposes.)

Summarising, epistemic logic and semantic information theory are compatible inasmuch as the accessibility relation may be taken to be a device that assigns, at every state w, a set of states that, by virtue of being candidates for the actual state, define a dichotomous ordered partition of the familiar sort.

What about resource bounds? The possible world semantics described above does not lend itself to the encoding of resource bounds, but there are alternative approaches that do, such as that of Konolige (1986), who essentially replaces accessibility relations by pairs (Γ, Δ) in which Γ is a set of sentences (initial beliefs) and Δ is a deduction algorithm which may be rendered incomplete by constraints on time and memory.

NON-MONOTONIC LOGIC

How can one implement mechanisms that support the formation of defeasible beliefs? An attractive option is to use default rules. One way to think of a default rule, characteristic of the approach known as minimal model semantics, and specifically the more modern formulations of that approach (Shoham 1987; Krauss, Lehmann & Magidor 1990; Lehmann &
Magidor 1992), is to see it as a semantic ordering, which is to say an arrangement of the states into levels (an arbitrary, as opposed to dichotomous, ordered partition). The states at the lowest level are the most normal or most preferred states, those at a level higher are less normal, and so on. This is a natural way to reflect statistical or heuristic information. If, for example, it is evident from past history that the FHS is typically in state 11, less usually in state 00, and very seldom in states 10 or 01, then this suggests a default rule represented as follows:

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The default rule supports the formation of defeasible beliefs by refining the information available to the agent via observations. Given the agent able to hear the fan but not detect the heater, and assuming the FHS to be, for the sake of argument, in state 11, the information available via observation is represented by

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which may be refined by the default rule (in a manner we shall gloss over) to produce

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If we take the agent's beliefs to be sententially represented by the logically strongest sentence true in the states at the bottom level, then the agent now
believes, defeasibly but accurately, that 11 is the actual state of the system (i.e. has the belief \( p \land q \)). Lest this seems too good to be true, reflect that had the FHS been in the actual state 10, the agent would have had exactly the same information available via observation, and would have applied exactly the same default rule, and would have ended up with exactly the same defeasible belief which in this case would have been false. But the circumstances would have been exceptional.

Summarising, minimal model semantics uses arbitrary ordered partitions to refine the information available to the agent via its sensors, and sententially represents the defeasible beliefs of the agent by sentences true in all the states occupying the bottom level of the resultant ordered partition.

**INFORMATION TEMPLATES**

Default rules have a natural representation as not-necessarily-dichotomous ordered partitions of states, and once a default rule is used to refine the information available to an agent via observation, the result may very well also be an ordered partition consisting of more than two blocks. There is an upper limit, however. A system consisting of \( k \) components (and whose states are therefore determined by the status of \( k \) elementary facts, corresponding to \( k \) atoms in a propositional language) has \( 2^k \) possible states. Thus a partition of the set of states can have no more than \( 2^k \) blocks.

By an *information template* we understand (loosely speaking) the arrangement of at least \( 2^k \) levels, visualised perhaps as empty boxes stacked on one another. Having in mind that the question of overriding interest to the agent is 'What is the actual state of the system?' we adopt the convention that the lowest box is for states that are considered most normal or most likely candidates to be the actual state, and that the uppermost box is reserved for states that the agent definitely rules out as candidates. In between, the intuition is that moving upwards corresponds to being regarded as less normal or less likely to be the actual state. For the moment, of course, the boxes are empty.
By a *templated ordering* of the set of states we understand an allocation of states to the boxes of an information template. This allocation must exhaust the set of states and allocate each state to no more than one box. Formally, a templated ordering is (induced by) a function from the set of states into the set \{1, 2, ..., 2^k, ..., m\}. State \(u\) is below state \(w\) if the value assigned to \(u\) is less than the value assigned to \(w\). Templated orderings are a special case of the modular partial orderings of Lehmann & Magidor (1992).

A templated ordering may allocate one state to each box of the relevant information template, but more usually would allocate several states to the same box, thus leaving some other boxes empty. Even if empty, the boxes exist and can continue to play a role in various ways. Thus a templated ordering has more structure than an ordered partition of the sort encountered in the previous section. The key step forward is the availability of an uppermost box for definitely excluded states. The ordered partitions of the previous section could not represent definite exclusion, and so were able to support only the sentential expression of an agent's defeasible beliefs (the sentences true in all states at the bottom level). With templated orderings, it becomes possible to distinguish between those beliefs to which the agent attaches the greatest weight (the cautious beliefs, or knowledge of the agent) and those beliefs which go to the limits of plausibility (the brave or defeasible beliefs of the agent). The agent's knowledge consists of all sentences true in all the states below the uppermost level, and the agent's defeasible beliefs comprise all sentences true in all the states occupying the bottom level. (For 'all sentences' we may substitute 'the logically strongest sentence'.)

By way of illustration, suppose the FHS is in state 11, that the agent can hear that the fan is on but cannot detect whether the heater is on, and that the agent is equipped with a default rule according to which state 10 is more normal than 11. The agent is definitely able to rule out states 01 and 00, because able to observe that the fan is on and thus that the first coordinate must be 1. If the agent views 11 as only moderately less normal than 10, the following templated ordering would be a suitable model-theoretic representation of the information available to the agent:
The agent's knowledge, in this case, may be represented by the sentence $p$ (essentially the sentence whose content elements correspond with the states in the topmost box, or equivalently the sentence true in all states below the topmost box). The agent's defeasible belief is that $p \land \neg q$, this being the sentence true at exactly the states in the bottommost box. (The defeasible belief happens to be false inasmuch as the actual state is 11, but such is at times the fate of defeasible beliefs.)

If the agent's default rule led to the view that 11 is grossly, rather than moderately, less normal than 10, but not entirely ruled out, then the mechanism of refining observational information by default rules gives the following templated ordering:

We note that the agent's knowledge and defeasible beliefs (in their sentential form) would be precisely the same as before. However, in the larger picture, there is a difference. Agents must act, and in the case of rational agents, their beliefs guide their actions. Often actions have risks. Pulling
the red lever to shut down the nuclear powerplant may, if judged later to have been unwarranted, cost the company money and the agent a job. Not pulling the lever may have even worse consequences. It follows that in a model that links the epistemic state of an agent with actions, it is desirable to take into account the intensity of conviction (or degree of justification) of a belief. The templated ordering allows nuances of intensity to be recorded and used in determining whether thresholds for various actions have been exceeded. Thus the intermediate levels of a template do have an important contribution to make.

THE ROAD AHEAD

If information templates are used to represent the epistemic states of an agent, then the journey towards relativism in the use of the term 'knowledge' jars to a halt long before the extreme is reached in which all knowledge is opinion and one opinion is as good as any other. By specifying criteria according to which states are shifted upwards in a templated ordering, grounds may be established for differentiating between knowledge and less well-justified beliefs. Such criteria would range from the operation by which a default rule refines observational information to the incorporation of judgements as to reliability of information from other agents.

We have not touched on the interesting question of revision or update of information. This is an active field, and the notion of information templates holds promise of contributing to an understanding of the distinction between various forms of belief change. For example, should a new observation provide information that is inconsistent with a current defeasible belief but not with the agent's current knowledge, then the agent should judge that the system continues to be in the same state as before, and merely revise the defeasible belief. But should the new observation be inconsistent with the agent's knowledge, then a judgement that the system has changed state would be in order, and the agent should be prepared to make a more radical change (update) to its spectrum of beliefs, possibly changing its knowledge too.
Also promising is the reformulation of epistemic logic so that accessibility relations may be replaced by functions that assign, to each state, a templated ordering of states. This would be a proper generalisation of the present assignment, by the accessibility relation, of what is effectively a dichotomous ordered partition to each state.

Finally, not much has been said about default rules. An entire industry is engaged in the classification of different kinds of default rules, some numerical (probabilistic, or fuzzy, or other) and some non-numerical (often based, as in the minimal model semantics, on stereotypes or a notion of typicality, but sometimes based on other qualitative methods). How to revise default rules in the light of evidence brings us to one of the most active fields of artificial intelligence, learning. There are many different kinds of learning, some modelled by neural nets, some by symbolic methods. The question of learning applied to default rules in the context of information templates is still largely untouched.

References


IS AN AFRICAN SCIENCE POSSIBLE?

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1 INTRODUCTION

To ask whether an African science is possible, is to ask this question within the context of still larger questions: Is science acculturated? Is there a culturally determined science? It could, however, also be asked from the perspective that science is culturally independent. The same question would then mean: Is science possible in Africa? Part of the object of this article is to arrive at a position where the right question could be asked.

In 1995 the fourth Pan African Congress of Mathematics - i.e. a congress of African mathematicians and scientists - was held in Morocco. One of the speakers, Prof Loyiso Nongxa, from the Department of Mathematics at the University of the Western Cape, claimed that African mathematics is not only possible in principle, but existed in history and exists in present day reality. He could not understand how a colleague could conclude that there was no such thing as 'African mathematics', a view he regarded as incomplete and biased (Nongxa 1996:5). Nongxa was convinced that a hidden frozen mathematics of different cultures, including those of Africa, does exist and is being studied.

It is often regarded as debatable whether a Chinese, Japanese or Indian science exists, but as certain that a culturally determined mathematics is impossible. Mathematics is seen as an univocal exact science with no place for alternative interpretations – let alone cultural influences. Not so according to Nongxa, and he is not the only one who thinks this way! The conceptualist school in mathematics agrees. It is argued here that mathematics is culturally determined, e.g. the gravitational constant of nature which arises as a theoretically undetermined constant of proportionality in our mathematical equations, is an artefact of the particular mathematical representation we have chosen to use for the
gravitational force. In this sense G is a cultural creation, which reflects our inclination to express natural phenomena in a particular way. Thus our minds imprint mathematical ideas upon experience.

It also reflects something of the opposing belief that cultural elements completely condition our mathematical experience of nature, because nature has impressed mathematics onto our minds during the course of our evolutionary adaptation. Of course, if this is so then we cannot expect it to hold good when confronted with newly discovered phenomena outside of everyday human experience. '... there are places where no past evolutionary history could have produced the requisite concepts' (Barrow 1988:242,243).

According to the conceptualist line of argumentation one can certainly detect specific cultural biases in the way mathematics has been and is being done. The British style which eschews general formalism and abstraction for the sake of elegance alone, is biased towards applications and inspired by the desire to solve practical problems. The French, by contrast, are attracted by formalism and abstraction as epitomised by the encyclopaedic projects of the Bourbaki group (cf. Barrow 1988:242,243). Such national styles are, according to conceptualism, not mere harmless irrelevancies, but indicate a deep seated cultural subjectivity that colours the development of all human mathematics. This cultural bias then dictates the possible laws and explanations available to scientists in their representation of nature (Barrow 1988:243).

We are going to examine this relationship of science to culture more thoroughly in later sections. Let us ask at this stage: To what extent is mathematics culturally determined? Could the Bourbaki style not be understood and used by British formalists and vice versa? Or is the Bourbaki style actually a French cultural universal in mathematics?
2 IS THERE AN AFRICAN SCIENCE IN TRADITIONAL AFRICA?

With 'traditional' here is meant African cultural communities which are neither Arab nor Western. There is no single African culture; only a manifold of African ethnic and cultural groups with divergent traditions, rites, practices, etc. And yet, Africa is, to a large extent, homogeneous. African ethnic groups share many commonalities - an outsider could fairly easily distinguish African from European or Asian cultures. C.B. Okolo of Nigeria says:

Africans are not one but many peoples and races with a diversity of cultural beliefs and traditions ... (Ghana, for example, has 95 distinct language groups) ... [but] ... anthropologists today do not dispute the fact that black Africa, for example, exhibits a certain cultural unity (Okolo 1993:478).

When one talks of traditional Africa, reference is usually made to magic and witchcraft. The perception from a Western perspective is that these are not science, but practices embedded in superstition. European (Western) science developed from mythical explanations¹ of phenomena among the Greeks who, at a certain point, made a revolutionary turn by having abandoned mythical explanations in favour of rational explanations. Therefore we find the first attempt at a Grand Unified Theory (GUT) with Thales 7BC. Africa obviously had no contact with and underwent no influence by the Greeks but developed independently of Greek rationality. Arab-Persian Islamic science and culture, on the other hand, were not only influenced by Greek philosophy, but carried this spirit of rationality much further on the scientific and technological level.

Does this mean that for African science to exist Africans must have been influenced by the Greeks? Is such a 'Greek stage' necessary? I do not think so. Chinese mathematics and astronomy got well under way at the

¹ Here we already presuppose that a myth could also be explanatory.
beginning of the previous millennium without recourse to Greek rationality and science. Although this development was inhibited and became largely a sterile science, it supports my view that scientific awakening and development could occur independently of the Greeks. Further support could be found in Babylonian mathematics and astronomy. The so-called theorem of Pythagoras was known and studied in Babylonian mathematics 1700 years before Pythagoras (4BC).

However, I think that the Rubicon that the Greeks did cross is a necessary condition for scientific development and progress: the acceptance of the spirit of rationality, i.e., rational, logical, coherent explanation of phenomena, in which a distance between the epistemological subject and object is kept. I think this was the case in China and, if I am right here, the spirit of rationality is not a Greek thing but something human. My argument, however, raises the question: What is the role of culture in science? Is science and culture so interlinked that Tahitian, Peruvian and African science are all different sciences? Can Western science with its clear Greek roots be regarded as a universal science? Can Western scientists decide on the scientificness of African or Tahitian science? These issues will be examined by looking at the question: Is an African science possible?

It appears, contrary to my earlier reference to superstition, magic and witchcraft, that traditional African thinking was empirically oriented (Gyekye 1997:26). Observation and experience constituted a great part of the sources of traditional knowledge; proverbs resulted from reflections on specific situations, events or experiences; even metaphysical concepts such as destiny or fate, were broadly speaking, reached with reference to experience in an inductive way (Gyekye 1997:26).

The empirical basis of knowledge had immediate practical results in such areas as agriculture and herbal medicine: ancestor farmers knew of the system of rotation of crops, they knew when to allow

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2 This distance should, of course, not be pushed too far as happened in positivist science and in a strong version of Cartesian dualism.
a piece of land to lie fallow for a while; had some knowledge of the technology of food processing and preservation, and a great deal of evidence about the knowledge of the medicinal potencies of herbs and plants – the main source of health care delivery systems long before the introduction of Western medicine (Gyekye 1997:26-27).

Together with this food preservation, food fermentation and herbal therapeutics also occurred. This being so, can we speak of African science existing for millennia in Africa? Is this science or rather technology? Is there a coherent theoretical frame of reference behind this African empirical approach? Robin Horton thinks this is the case. This will be pursued later. Fact is, agricultural and medical practices did occur in traditional Africa and had an empirical basis. Perhaps, these even display something comparable to inductive logic. But, when saying this, are we not using Greek-Aristotelian and Western logic (induction as a systematic and methodological procedure derived from Aristotle) as criterion?

3 AFRICAN SCIENCE AS SOMETHING TOTALLY NON-WESTERN – THE VIEWS OF K.C. ANYANWU OF NIGERIA

The knowledge arrived at with the Western principles of understanding is not the knowledge of the African cultural reality but enlightened rationalism of knowledge emancipated from the African cultural world (Anyanwu 1988:17).

According to Anyanwu the African’s mental processes are different from the Western mind; the African thinks from different assumptions, and has world views which fit experiences different from those of Western scientists. Modern and contemporary science, be they Newtonian, Einsteinian or quantum theories are per se Western and exhibit a typical Western mind set. From this it follows that science in Africa must necessarily be something different from Western science because, he says,

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3 I do distinguish between science and technology, even though in modern and contemporary times, the two can hardly be separated from each other.
the culture behind Western science and thinking and that of Africa is so divergent, that any appeal to empirical and rational methods has no meaning and relevance in Africa. Problems would be ‘wrongly’ formulated if transferred to Africa, so that the methods and solutions would be equally ‘erroneous’. Not only the methods and the frame within which the empirical is understood are different, but Anyanwu (cf. 1988:83) also postulates that a different logic operates in African thinking. Should a contemporary science emerge in Africa, it would follow that such a science’s starting point, assumptions and theories would be different. A different world view (as in Africa), according to his line of reasoning, leads to a different science and knowledge. There are no culturally neutral standards of knowledge and no universal criteria for objectives. In fact, speaking of standards and objectives, is already introducing a cultural bias and a different world view. Anyanwu puts it succinctly:

We are therefore entering into a cultural world whose philosophy of integration, whose principles of understanding and of aesthetic continuum differ completely from the Western ideas of what constitute the trustworthy knowledge and reality. ... we do not have a neutral world philosophy applicable to all cultures at all times and in all places. Every philosophy is cultural philosophy conditioned and limited by culture. All cultures may observe the same facts (trees, rivers, heavenly bodies, life and death, good and evil, joy and suffering) but their basic assumptions, theories and standards with which they interpret such facts are different. Differences of cultural philosophy depend on the difference of the basic assumptions and theories about reality. ... We must examine the basic assumptions of cultures and the methods which the owners of the culture use to arrive at a trustworthy knowledge of what they believe reality to be. There may be resemblances or similarities between the philosophies of different cultures, but these similarities do not involve identities. (Anyanwu 1988:78, my emphasis).

Another Nigerian, Okafor, in conjunction with Oruka from Kenia, argues similarly and criticises Western thinking in the guise of a disinterested,
universalistic, transcendental, speculative discourse which served as the ultimate veracious buttress of European conquest: 'We reject this orientation born of modern European thought which "presupposes a single culture, a single religion, a single global conformism"' (Okafor 1993:98).

A problem here is, granted that different cultures can and do interpret the same things (trees, etc.) differently, how would one know when and where one has a theory? In terms of what would one recognise something as a theory? - that is, given that theories in Western science and in Africa are different in terms of cultures and world views. What would Anyanwu regard as reliable when he refers to reliable and trustworthy knowledge, especially about Africans themselves? What would 'trustworthy' constitute? Is he not implicitly but also actually, appealing to the non-African reader? What would constitute knowledge, especially scientific knowledge? What would the function of knowledge be?

Nevertheless, Anyanwu states that the demand to be scientific is part only of Western science. So is the attitude of scepticism which goes with being scientific.

It [scepticism] is the product of logical reason doubting its own foundation. To spread this scepticism to African cultural experience and reality is completely naive. The philosophy of a collective people is not lifeless logic but profound beliefs, the feelings and emotions of the ideals (Aanyanwu 1988: 79-80).

With this 'Western' logic, he contrasts 'African' logic. 'Western science and [p]ure reason is always uncomfortable with contradictions and nothing is as contradictory as the African beliefs and behaviour. But this arises only from the standpoint of Western culture and logic' (ibid: 88. My emphasis). The African operates with the logic of aestheticism which holds that the whole is the real - knowledge is not a matter of fact but a complicated act of judgement involving facts and theories. 'The Africans do not only think about such concepts; they live and feel their realities. ... For the West such concepts are vague, not clear; subjective, not objective' (ibid: 95). The Western rationalist seeks definitions, proofs and believes in concepts. The
African as vitalistic, seeks inspirations, intuitive insights and believes in the personal (not impersonal). The Western rationalist scrutinises nature and the universe to wrest their forces from them, and he does this by detaching his ego as if he were not present in the world. The African, and so would an African science, strives to put himself in immediate and personal relationship with the soul of the world. The unity of the ego and the world arises from a mental attitude quite different from that of the West (cf. ibid: 88).

The African rejects the scientific procedure of distinguishing between 'particular' and 'general' knowledge. In an African science, according to this line of argumentation, every judgement is a synthesis of both the particular and general, and this in every simple moment (cf. ibid: 80).

This is the opposite of the sceptic approach. According to Anyanwu, for the African no major advance is possible in science and philosophy or in any work if thought is made to rest on scepticism, caution, mere observation of facts and the enumeration of isolated facts. Instead, Anyanwu argues,

> there must be the conviction of the unity of each thing with every other thing because only the conviction of an individual who believes that he has a clue to the knowledge of reality can overcome the scepticism of pure reason which arose from its inability to handle or grasp the complexity of vital experience (ibid: 82).

From this it appears that (a) African science would be holistic with the assumption of the interconnectedness of everything, (b) Western science is fundamentally sceptic and dualistic with the assumption of isolating things from each other by pure reason. The conclusion, (c) then is, Western and African science and thinking are incommensurable. The one cannot be transferred to the other.

We shall later examine the two premises. At this stage I think that being sceptic and being critical is here confounded with each other. In my view the two ought to be distinguished. Scepticism denies the possibility of
knowledge and truth as such, and is sometimes destructive. Not so with a
critical stance. Criticism questions things, doubts as a method, keeps a
distance, imbibes the spirit of rationality (and creativeness) but is open
minded and open ended.

Western science according to Anyanwu's thinking brings a duality or
dualism between world and experience: All contradictions which human
being faces, stem from the duality of experience, e.g. contradictions
between one and many, individual and universal, time and eternity, freedom
and necessity, reason and sentiment (cf. ibid: 85,86). Starting from this
Anyanwu opposes not only what he calls scepticism, but also a critical
stance - a critical distancing from the world, and the distance between
epistemological subject and object. The result of scepticism for him, is two
contradictory theories of knowledge, viz. rationalism and naturalism (with
naturalism I think he actually means empiricism). The wrongness of
Western science, according to Anyanwu (cf. ibid, 85,86) comes out in that
Western universities teach both these theories without any embarrassment
as trustworthy knowledge of reality and then suppose naively that they
apply to all cultures, including those of Africans.

When criticising this distancing in Western science between humans and
world, epistemological subject and object, he claims (1988: 90,91):

It does not mean that the African does not know the distinction
between a tree and a goat, a bird and a man. Rather, the
ontological relationships among life-forces do not permit him to
see things in isolation. ... the self and the world interpenetrate
each other in such a way that we do not know where the self
begins and ends for the world to begin... What the West considers
as material things are, for the African, vessels of mysterious
forces.

Speaking of detachment and distancing: 'The African maintains that there
can be no knowledge of reality if an individual detaches himself from it. ...
The African, a life-force, is not a passive spectator of the universe but an
active participator of the life-events' (ibid: 94). Therefore Western and
African scientists work with different worlds. The West separates humans from nature and subordinates them to natural processes. African science and knowledge operates with a unitary world, whereas Western science operates with fragmented or dissociated views of reality (86). An African science, cannot base thinking and explanation on such a view which lacks unitary perspective.

This difference is emphasised further in Anyanwu’s claim that Western science sees material processes in space and time as the real. That which does not fit into this framework is termed superstition. This is the opposite of the African approach. Okolo in similar vein has this to say about the African view of reality:

... for him [traditional African] the ultimate reality is spirit, God, or consciousness, not matter. This is to say that the African is not a materialist in the philosophical meaning of the term. ... He was no materialist. Indeed nothing was further from his mind than a materialistic philosophy of existence. It made no appeal to him' (Okolo 1993:479).

Furthermore, African culture centres on the self and is thus personal, unlike the impersonal mode of Western science. Personal experience again refers to the totality of a human being and its faculties; it does not address itself to reason alone. The truth of this experience is lived and felt not merely thought of. A world that has no reference to the person, to the self, has no meaning for the African; for the African humans and nature are not two independent and opposing qualities; they are inseparable (the unitary view) (cf. Anyanwu 1988: 86,87). Yet, C.B. Okolo (a fellow Nigerian) interprets this differently. He deflates a strong unitary view: 'As in the Platonic tradition, reality for the African is dualistic, namely, the invisible and the visible or the experienced universe. But unlike the instantiated world in Plato’s theory of reality, for the African this world or the phenomenon, is real, not a mere shadow of the invisible' (Okolo 1993:479). Kwasi Wiredu of Ghana, with reference to the Akans, likewise sees a duality in experience:
... there is a conception of a hierarchy of existence, starting with inanimate things at the bottom and climbing through the realms of plants and the lower animals to that of human beings, the ancestors and a variety of extrahuman beings and forces up to the supreme being at the apex. (Having touched upon inanimate things, let me take the opportunity to debunk the routine attribution of animism to all Africans. The Akans, at least, regard some things as lifeless. For them dead wood is quintessentially dead and what is so tragic about a corpse is that it is lifeless – the life principle has left it!) (Wiredu 1992-93:46).

He also rejects the application of the term 'mystical' to the Akans:

We do not have a special experience in which the subject attains unity with the highest reality, directly apprehending everything as identical with everything else and yet as distinct: Nothing is farther from traditional Akan modes of thought and experience than mysticism in this sense (Wiredu 1992-93:46).

An African science would be possible if it is based on the African world and culture, and also when it strengthens the inherent vital force or vital relationships in the universe (cf. Anyanwu 1988:86,87). The ideal of Western science and culture as the conquest of nature where science is a tool for this conquest, explains, according to Anyanwu, why Western culture is so belligerent (88). An African science cannot be possible in this way: nothing is nature and the universe is lifeless or soul-less.

For the African everything is filled with or bedded in life-forces. Thus, for an African science imagination, intuitive experience and feelings would also be modes of knowing. Such a science would be based on another but balanced edifice of truth (cf. 89) and would be possible because, unlike Western science, it has made up its mind as to what nature is, whereas the Western scientific view of nature changes constantly (cf. 91). 'The West believes that reality is a material process in time, hence whatever can be seen with the eyes, touched with the hands, measured and quantified. Secondly, the world is said to be inert and the subject (spirit or mind)
independent of matter' (92). Western science treats things as mechanical forces and motions, laws, charges and mass, all in space and time (96). For Africans (and so a possible African science) space and time do not exist independently – they are forces themselves and they interact with forces. In a possible new African science space and time would be lived, felt and dependent on intuitively grasped experience because they are not mathematically defined and measured (as in Western science); they are multi-dimensional - the future can be long and short and so also the past; but the past and the future find unity in Now, that is, the present, living experience. In other words, past and future are here and now (95,96).

The possibility of such an African science is consistent with Anyanwu's view that science is culturally determined. The West has its science and so Africa can have its own. To 'dump' Western science on Africa is thus inappropriate. We shall examine the cultural realities of science later, but at this stage I would like to make the following comments:

That Anyanwu contrasts Western and African thinking is no problem. It makes sense just as Eastern ways of thinking can be contrasted to those of the West. I do, however, have a problem with his points of comparison or contrast: Is it two sciences that he contrasts or is it science against life-worlds? (All cultures, including the Western, have life-worlds.) I think his point of comparison is, and ought to be, rather that of African life-world approaches to those of Western life-worlds. This would then lift science out of a particular cultural context - an approach which still has to be discussed. In general then, Anyanwu accepts the possibility of an African science and has outlined its starting points and world-view. To reject this simply because one is acquainted with Western science only, would not be acceptable.

With reference to his view of logic. He refers to an aesthetic African logic and critically contrasts it with Western logic. Yet when he criticises Western rationalism and naturalism (empiricism) which result, according

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4 I maintain a distinction between a scientific world-view and a value-systems world-view.
to him, from the West’s detachment of subject from object, he sees these views as contradictory. This is correct in a sense, but he wants his appeal to contradiction to be accepted as ground for rejecting the West’s subject-object dualism. Anyanwu is thus appealing to a law of the same logic which he is arguing against, viz. the law of non-contradiction. Either his argument for a culturally dependent logic is wrong or he is implying that a cultural universal or rather a culturally independent principle exists which makes his argument much less extreme.

4 CAUSAL EXPLANATION IN AFRICA

To consider the possibility of an African science, I think it is necessary to consider causal thinking in Africa. The reasons are twofold:

(a) In Western science, from the time of the Greeks (especially Aristotle), through modern up to contemporary science, causality plays an important role. Science needs explanations so that experiences and observations, which as we saw earlier on, are in Africa empirically oriented (Gyekye), can be made theoretically intelligible. Science goes further than observations or phenomena, and sees these in the light of causality. Gyekye (1997:27,28) is right when he sees causality as crucial to the pursuit of science. As we saw in the previous section Anyanwu draws very strong contrasts between African thinking and Western science and, among others, criticises mechanical explanation, which, according to him, does not apply in Africa because causality works differently for the African.

(b) An implication of this criticism of Anyanwu's against mechanical (causal) explanation may be that science in the Western sense is not possible in Africa.

As Anyanwu (1988:92,93) explicitly claims:

So, the West seeks rational causality in all things. What happens if nature is alive, if spirit permeates the whole universe, if consciousness cannot grasp the factors of causality? Effects
would then be interpreted as magical and so also the method ... He (the African) believes that due to this unity and the nature of things, "secret", "unknowing" or "unforessen (sic)" forces intervene in the course of events. ... The West calls this an accident, but accident is only a confession of ignorance or lack of consciousness. ... So, the whole truth about cause is magical, that is, it belongs to the non-material world.

Causality would, for the African, according to Anyanwu, freeze everything into a static unreal world. For African thinking everything is in everything else and conditioned by everything else; there are no static or permanent positions in the universe. There is no firm hold anywhere. A Western causal science would not only freeze reality, but would also be dangerous to the African: 'The African believes that objects are charged with forces, that they must be approached with caution, that the forces have good or evil effects depending on how they are approached and used ... An unnecessary alteration of the forms of objects could release hostile forces that would bring ruin to the people' (93). So, not cause, but rather caution is appropriate!!

However, according to both Western and Asian academics, causal thinking is quite prevalent in Africa. When referring to causality here, I do not mean deterministic or mechanical causality (*causa efficiens*), but in a life-world, and so pre-scientific sense which I see not primarily as a chronological, but rather a logical-epistemological distinction.

The Ghanaian Gyekeye (1997:28) puts causal thinking in Africa in this way:

Empirical causation, which asks what- and how-questions, too quickly gave way to agentive causation, which asks who- and why- questions. Agentive causation led to the postulation of spirits or mystical powers as causal agents; ... It is the lack of distinctions between the

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5 With 'pre-scientific' I do not think in terms of historical stages of e.g. pre-logical, pre-scientific, as Levy Bruhl initially thought it to be, even though such stages may be taken seriously.
purely material (natural) and the immaterial (supernatural, spiritual) that led to the postulation of agentive causation in all matters. For, in a conception of a hierarchy of causes it was easy to identify the spiritual as the agent that causes changes in relations even among empirical phenomena.

It could be mentioned that agentive causation is not alien to Western science. A distinction is made between causal determinism and ontological freedom in the case of humans. Human action and behaviour can be explained in terms of reasons (equivalents of causes) in which case humans are referred to as agents. They are self-causing agents within limits. In Africa, however, the agentive causation gets a further connotation of spirits, or forces.

Is it not the case that all human beings throughout the world, in a pre-theoretical, pre-scientific, stance want to make sense of the world, of events that occur and which sometimes touches their lives in an important way? I would claim that this is the case. It is also common sense (common too in the sense of being the case world-wide, including Africa) to explain things in terms of causal sequence. All human beings wish to make sense of things by explaining them. Why? To understand. Why? To get a hold on the world, to find their way in their world as instinctive drives alone apparently do not yield answers and ‘explanations’ for everything. Humans are interpretatively directed to their world. Humans are interpretation.

As part of this human trait, humans look for antecedents to events that are consistent with them in some way. R. Horton is adamant that African thinking not only seeks antecedents as causes, but that these causes are not necessarily always of a supernatural nature, as is often believed. This can be seen in the search for causes in traditional Africa as diagnostic of certain diseases: The diviner who diagnoses the intervention of a spiritual agency is also expected to give some applicable account of what moved the agency in question to intervene. And this account very commonly involves reference to some event in the world of tangible visible happenings. So if a diviner diagnoses the action of some witchcraft influence or lethal
medicine spirits it is usual for him to add something about human hatred, jealousy and misdeeds which brought such agencies into play - it is a kind of social analysis. 'The point in all this is that the traditional diviner faced with a disease does not just refer to a spiritual agency; he uses ideas about this agency to link disease to causes in the world of visible tangible events' (Horton 1995:201,202).

Even though the causes may be referred to more in personal idioms, I think one may claim that causal thinking is prevalent in traditional Africa. Furthermore, I think that causal thinking as developed by Western science, was not possible without the human life world, a common sense experience of the world in terms of causes. Western philosophers and scientists like Galileo, Descartes, Newton, Kant, and not to forget Aristotle, are to be credited for having placed things and events in a causal framework which is wider than the one which is provided by life-world common sense. This 'wider than' did not fall out of the sky. It was novel, but not completely. It had its logical and chronological antecedents in common sense life world experience. In a sense we can talk of a proto-causal theory.

Saying that, it follows that it should be possible for an African science to emerge or to have emerged. It did not. Why? I think there is a logical explanation, to which I shall return.

5 IS TRADITIONAL AFRICAN THINKING A POSSIBLE SCIENCE PARALLEL TO WESTERN SCIENCE? THE VIEWS OF ROBIN HORTON

According to Robin Horton, a Western academic living in Nigeria, African science is not only possible, but traditional African thinking is, to a large extent, quite similar to Western science. It gives theoretical explanation as does Western science. In fact, he argues (1995:53), pre-literate religious belief statements in Africa can be taken at face value and be analysed as real attempts at explanation. They can be intellectually interpreted and there has been development of the ideal of objective understanding:
Thus the emergence of an ideal of objectivity does not mean the growth of an interest in explanation where there was none before. ... Pre-objective cultures, then, are not cultures where the desire to make sense of the world is absent. They are cultures where this desire is still intricably interwoven with many others (Horton 1995:54).

I think the main thrust of Horton’s arguments is that African traditional thinking is theoretical, just as Western science. He sees this as going against the current view that traditional thinking is only practical and further magical-personal from which theory and theoretical explaining is absent. The application to Africa of the colloquial opposition between ‘theory’ and ‘practice’ is doubted by him:

... one of the principal intellectual functions of traditional African religious theory is that of placing everyday events in a wider causal context than common sense provides ... it is reasonable to suppose that these practical concerns have played as great a part in stimulating the development of theory as they have in stimulating the development of common sense (Horton 1995:56).

African explanations cannot be regarded as mistaken or wrong because they feature invisible personal beings - animistic explanations in personal terms also occurred in Europe. There is nothing prima facie unreasonable about animistic explanations. What is more, when we come to the 'higher' faculties of humans (I think he refers to consciousness, reasoning, thinking, making choices), it appears that non-animistic, non-personal explanations which presuppose inanimate matter, become dubious (cf. p.60). This seems to be creating too strong a dichotomy between African thinking and Western science. To play down the explanatory aspect of pre-literate thinking and belief-systems is patronising. It is wrong to assume that Western theories are in an absolute and final sense right whilst pre-literate theories are in some absolute sense wrong – the dichotomies of wrong/right mistaken/correct are, in fact, far too strong to do justice to the relation between the beliefs of pre-literates and those of modern Westerners (59). In fact, Horton argues that this dichotomy is relativized by the fact that
Western science is not cumulative, but grows through the overthrow of a good theory by one that gives wider coverage of the data, and, again, through the overthrow of this better theory by one that gives still wider coverage. Examples are Newton and Heisenberg: 'What I have tried to point out here is that the rightness of the current Western belief system is in the nature of things transitory; and this in the sphere of "higher" human behaviour at least, where pre-literate belief systems may from time to time be the source of insights that seriously shake some Western foundations' (61).

Instead of absolutely dichotomous then, Western physical theories and those of Africa are more on a par even though as different alternatives. Horton (1995:627) puts it this way: 'In tackling the questions I started out with the intellectualist assumption that both the gods and its spirits of traditional Africa and the ultimate particles and forces of the Western world view were alternative means to what was basically the same explanatory end' (my emphasis).

Horton goes further by arguing that a study of pre-scientific thought systems will give us a clear view of the nature of science. He quotes Emile Durkheim's argument that the logic of participation in pre-scientific cultures are not so alien to scientific logic. There is a connection between the two; scientific logic was born out of this 'common sense' logic. The explanations of contemporary science are surer of being objective because they are more methodical and because they rest on more carefully controlled observations, but they do not differ in nature from those that satisfy primitive thought; we also explain by showing how one thing participates in one of several others; every time we unite heterogeneous terms by a internal bond, we forcibly identify contraries.

Of course the terms we unite are not those which the Australian [referring to the Aborigines - author] brings together; we choose them according to different criteria and for different reasons; but the process by which the mind puts them in connection do not differ essentially. Thus between the logic of religious thought and the logic
of scientific thought there is no abyss. The two are made up of the same elements, though unequally and differently developed (E. Durkheim quoted by Horton 1995:72).

According to this, the ideas of scientific logic are essentially of religious origin, even though science gives them a new elaboration in order to utilise them, and purge them of all accidental elements. Both traditional religion and scientific thinking pursue the same end. One could deduce that according to this line of argumentation there is no category difference between Western science and that of traditional Africa, but only a difference in degree. But does claiming this not presuppose a superiority of the West? Many would regard this as expressing something of a patronising colonial mentality.

In line with this, it could be seen that the quest for explanatory theory as basically the quest for unity underlying diversity, for simplicity underlying complexity, for order underlying disorder, for regularity underlying anomalies, occurs in African thinking as in Western science (198). Many modern writers deny just this because they think that traditional thinking is in no sense theoretical thinking, exactly because these quests are not part of it. To state his case, Horton refers to African cosmologies. The gods of the Kalabati tribe e.g. form a scheme which interprets the vast diversity of everyday experience in terms of the action of a relatively few kinds of forces, namely ancestors, heroes and water-spirits. 'Like atoms, molecules and waves, the gods serve to introduce unity into diversity, simplicity into complexity, order into disorder, regularity into anomaly' (199). As in Western science, a person has a choice of wider or less wider theories. It is typical of African religious systems that they include, on the one hand, ideas about a multiplicity of spirits, and on the other, ideas about a single supreme being – though the spirits are thought of as independent beings, they are also considered as so many manifestations of or dependants on the supreme being, which is a conjunction of the one with the many. The parallels in Western science is there, according to Horton: ‘The atoms of lower-level theory become mere manifestations of particles postulated by the higher level theory’ (211). The point is that different levels of thinking
are there in all these systems – a difference of degree and not of category or in principle.

Furthermore, both draw on analogy and metaphors, even though those of Africa are more couched in 'personal idioms'. Many writers have considered this sort of abstraction (i.e. analogies, metaphors) to be one of the distinctive features of scientific thinking. But this, like so many other such distinctions, is a false one; for just the same process is at work in traditional African thought (215). Horton substantiates this difference in degree with examples, e.g. Rutherford's planetary model of atoms. The relations between common sense and theory are 'essentially the same as they are in Europe' (209).

Although Horton concludes that African systems do allow for alternatives and are less closed than Westerners are inclined to think, he states that logic and philosophy in a restricted sense, are poorly developed in traditional Africa as Africans did not pause to reflect upon the nature or rules of e.g. cosmologies. Yet most African traditional world views are logically elaborated to a high degree and has an eminently rational character (229).

Whereas Anyanwu strongly contrasts Western science and that of Africa, that is, stresses discontinuity, Horton sees a definite continuity between Europe and Africa. Should one follow Anyanwu's line of argumentation, then an African science is quite possible but in this case it would be something totally different from Western science. It is not clear from Anyanwu's thinking what such an African science would look like, or in terms of what it would be called science, or what the ends of such a science would be. Should one follow Horton's line of argumentation, then an African science would also be possible. In this case, it would be quite similar to Western science. In fact, as we saw, for him African thinking is already a theoretical explanation parallel to that of Western science.

I think that Horton has got a point in that traditional African thinking does also explain. The intention is also to understand problems and events in the world. As we have seen, it clearly uses causal thinking and explanation. I think that Horton is to an extent justified in seeing in African thinking (and
it would also apply to other pre-theoretical thinking, like that of the Australian Aborigines or Indian tribes in South and North America) structures and ways of perceiving and explaining the world, which enable us to understand the emergence of rational theoretical science. I would call these proto-theories of the world. What is more, insights from traditional thinking may become useful in and for modern or contemporary science. Because of their unique experience of their world their thinking and explanations may yield creative ideas for science, even though these may be embedded in a particular religious context of invisible spirits, forefathers and magic. There are such examples in medical science.

But, I have problems with Horton’s line of argumentation. His comparison is, to my mind, flawed. He actually had to compare pre-scientific thinking in Africa to pre-theoretical thinking in Europe. He claims, and rightly so, that the theoretical and practical are interwoven in traditional African thought. This is the case in the European (Western) life worlds too. In fact, this interwovenness of theoretical, practical, religious, aesthetic and political values is the definition of a Western person’s life world. In science, the process of abstraction disentangles this interwovenness and science gets under way. I am here referring to the life world and pre-theoretical experience of the Western person in 1999. Contra Horton, I would rather say that not only continuity, but commonalties exist. Although African nature religions do indeed explain in the way Horton indicates, I think that he pushes the parallel too far. The invisible beings’ explanatory function and that of non-observables in Western atomic theory, points rather at more than a difference in degree. African non-observables explain, but in no comparable Western theoretical sense. These non-observables are completely demythologised in science! Horton somewhat downplays the fact that the great non-theoretic religions like Judaism, Christianity and Islam do not explain or intend to explain the world and its geological or biological processes. Yet he is right when he states that ages ago Christians did use the Old and New Testament to explain the world. Many fundamentalists still do the same today. But even in such contexts the basic concern was with much more and with other things than explanation. So, I think Horton does downplay or minimise the discontinuity between the great monotheistic religions and African religions.
6  WOULD AFRICAN CULTURE(S) BE A DETERMINANT IN AN AFRICAN SCIENCE?

Let us begin with the one that must be namely, that only value neutral sciences can be universally valid ... Science cannot possibly be completely culturally neutral (Sandra Harding 1997:61).

The question above is part of the bigger question: Is all science culture dependent? We have seen that both Horton and Anyanwu make out a case for an African science, although in different ways. I would choose a path nearer to that of Horton than of Anyanwu. Saying that, I think this question about the cultural dependence of science needs to be addressed in view of the discussion thus far. It tends to crop up everywhere and every time African culture is discussed. According to Anyanwu's thinking science is culturally determined in a very strong sense. This includes all science, African, Western and Eastern. I cannot accept such a strong programme of cultural determinacy. This will imply total relativism so that communication between the different forms of 'cultural science' would hardly if at all, be possible. But even in such a strong programme one still applies the term 'science' to all 'cultural science'. I have to repeat my question: in terms of what would one call all these manifestations of 'cultural science' science? How will one know that it is?

It doesn't follow, however, that culture is totally irrelevant to science and science completely independent of culture. We have already accepted the continuity postulate and have therefore, to an extent, already presupposed something of cultural determinism. The question, however, is: in what sense and how is science culturally related or determined?

Rationality and science were enhanced by Greek culture e.g. by the politics of Solon and his reforms in Athens. If this is what she refers to I agree with Harding (cf. 1997:56) that abstractness and formality express distinctive cultural features and not the absence of culture. I disagree with her, however, if she means (as it seems) that science necessarily remains and must remain a specific cultural feature. In this case abstractness and
formality would remain but Greek cultural features. But, Greek culture and its interactions with Babylonian and Egyptian culture, was the propellant to get a theoretical non-mythical explanation of the universe going. Abstractness and formality thus, in my view, became universally accepted by science and thus by many other cultures. Harding disagrees. When modern (so-called Western) science is introduced into a non-Western culture, it is, according to her (56), experienced as a rude and brutal cultural intrusion because claims for science's universality and objectivity are seen as a politics of devaluing local concerns and knowledge. Africa and Asia were indeed seen as backward. This view was the result of the colonial mentality of the last three centuries of certain European powers, and its existence can neither be denied nor wished away. The colonial powers did introduce science to the colonies to an extent, and Newtonian science at that. It was believed that seen from the vantage point of science the indigenous peoples were ignorant and backward. Small wonder that science together with the new religion were perceived by the local people as foreign and associated with the colonial mentality of imperialism, something to be shunned.

Outlaw contests the 'pernicious myth that Africans are peoples of a decidedly "primitive mentality"' (Outlaw 1992/3:76) and I agree. But in my view, in real terms, the perception that science is a foreign intruder was not the result of teaching and favouring Western-European science as such, but of the package in which it came. It was perceived as colonial and imperial and thus as culturally unacceptable. Although Western science does have a Western-European cultural origin, and cultural propellants behind it, it yields something universal which transcends all cultures and contexts. Why and how? The answer lies within Asia and Africa itself.

Both Asia and Africa do see something universal in science and technology. Therefore they employ it. The reason lies deep, I think. Both Asia and Africa see something profoundly human in science even though, for contingent reasons, it was the West and Europe who launched it first in such a definite way.
Nobuhiro Nagashima from the University of Saitama, Japan in his *A reversed world: or is it?* accepts and outlines the cultural context of Japan in its interaction with Western science. Japan initially, like Africa, rejected Western science as something alien to Japanese culture. It even isolated itself from time to time from contact with the West. The first contact between Japan and the West took place in 1543, 1609, 1613. Tokugawa then followed a policy of seclusionism – but Western knowledge and science continued to filter into Japan through the Dutch establishment at Nagasaki, the only permitted channel to Europe (Nagashima 1973:107).

According to Nagashima Japan exhibited the following phases in reaction to Western science: 1) simple reproduction or copying, 2) adjustment or modification, and 3) refinement or *Japanization* of Western science (Nagashima 1973: 94-104). At the end of the last stage the product may not resemble the original. A good example according to Nagashima is the taking over of Chinese ideograms and script from China. This process from copying to the refinement stage was also noticeable in handicrafts, architecture and fine arts (105). The *Japanization* of 'foreign' Western science means that a corresponding indigenous Japanese element accompanied the development of science in Japan (105). Nagashima points out, however, that Japanese culture in some or other way realised something universal in Western science (94-96).

The feudal regimes already distinguished Christianity from science and unlike Africa did not experience science as part of imperialism, but as something universally human, which would benefit Japanese culture as well. So, the feudal regimes did not do much to discourage the study and entrance of Western science. Various sciences e.g. medicine, botany, astronomy, mathematics, geology, chemistry, physics and military science were established in the late Tokuzama era. The Japanese government in the first part of the 19th Century followed the policy of sending Japanese students overseas for studies, especially in the Netherlands (107,108). At the dawn of the 20th Century, Japan was equipped with various sciences and fairly advanced technologies. With a keen awareness of the difference between Japanese and Western cultures, Japanese scientists and institutions were equally keen to take up any new ideas and technologies (109).
A Japanese science was not only possible, but was realised. And an African science? In Africa Western science was enforced in different degrees in different places by colonial powers. Not so in Japan which, strictly speaking, was never colonised by the West. In fact, Japan as we saw, secluded itself from the West whenever it wished to do so.

Cultural difference creates possibilities for different cultures all to contribute to the expansion of knowledge about the world:

...the claim is that cultures’ different locations and heterogeneous nature expose them to different regularities of nature, and that exposure to such local environments is a valuable resource for advancing collective human knowledge. Cultures are repositories for historically developed and continually refined knowledge about different parts of nature .... distinctive interests have created culturally distinctive patterns of knowledge about this particular part of natures’ regularities and their underlying causal tendencies .... the local provides different kinds of continuously renewal resources for understanding nature.

Cultures’ interests, discursive resources, and ways of organising the production of knowledge are not stated and fixed, but continually changing as cultures transform themselves and are transformed by their interactions with each other and nature. But neither is nature fixed and unchanging (Harding 1997:57,58).

I concur with Harding’s argument: local cultural values have generated science. But only in that sense would I agree that science is not completely culturally neutral. I disagree with her view that after the mentioned birth, the thus culturally influenced science, became a universal scientific culture, so that you have universal Greek, Western, Chinese and Japanese science cultures. In my view this is one of the 'mysterious' things about science: A local culture or tradition of philosophy like the Pythagoreans, led to
mathematics being seen as applicable to nature. Nowadays Mathematics is accepted and employed by scientists in all cultures throughout the world. But without its birth in the Pythagorean cultural context, this universalisation would not have been possible. On the one hand, local cultural determinants; on the other, the universality of scientific knowledge and theoretical values.

On ground of this argumentation I would like to conclude that an African science is quite possible. The local African cultural context and interpretations could, in a similar way, generate scientific knowledge in Africa. Why has this not happened? Why is there Japanese and Chinese science in the sense described above, but not an African science? We saw that Outlook contested (and I think rightly so) the idea that Africans are 'decidedly primitive'. The existence of proto-causal theories and practical knowledge, as Horton and Gyekye indicated, are, I think, counter evidence to such an idea. Yet, as we just saw, an African science has not yet been launched. There must be a logical explanation, something must have and is inhibiting just that. We turn now to this problem.

7 WHAT INHIBITS THE TURNING OF POSSIBILITY INTO REALITY IN AFRICA?

Gyekye and Wiredu regard this as something serious. Both are optimistic that the inhibiting factors can be overcome. Both see an ossification and a sterile approach in Africa which inhibits the oncoming of science. Gyekye refers to an 'incomprehensible' inattention to the search for scientific bases:

The practised knowledge did not lead to any deep scientific understanding or analysis of nature. Observation made by them may have led to interesting facts about the working of nature, but these facts needed to be given elaborate and coherent theoretical explanation ... Science requires explanations that are generalizable, facts that are disciplined by experiments ... But the inability for lack of interest of the users of our culture to engage in sustained investigations and to provide intelligible scientific
explanations or analysis of their own observations and experience stumped the growth of science (Gyekye 1997:27).

Gyekye, like Horton, also points to the existence of causal explanation in traditional African thinking. 'Our culture appreciated the notion of causality very well, but ...' (Gyekye 1997:28). Where Horton sees in the African religions explanations by means of invisible forces as something theoretical, Gyekye sees it as a detriment. He thinks that Africa could select the best from Western science because not everything is bad colonialism. Postcolonial Africa cannot reject the whole corpus of the colonial heritage (Gyekye 1997:26).

Kwasi Wiredu in his *Philosophy and African culture* sees the obstacle to the realisation of African science in the prevalence of authoritarianism in Africa because an indoctrinated mind cannot make free choices: 'The very atmosphere we breath in many areas of life in our society seems to be suffused with an authoritarian-odour' (Wiredu 1980:2). There can be no choice in the absence of perceived alternatives.

This is a parallel to what inhibited science in China for millennia. Science did not get on its way in China, for the Emperor's authoritarian power down to grassroots level, inhibited scientific curiosity and wonderment. Chinese science, like astronomy and mathematics, every now and then seemed to be well under way, but every time it came to a halt and no further development took place.

Wiredu sees much that is positive in African culture and religion. However, he thinks the idea of an emotional, intuitive, essentially unanalytical, unscientific approach to the world at the cost of a rational, critical and objective habit of mind was and is wrong. He criticises Senghor in this vein:

Most seriously of all, Senghor has celebrated the fact that our (traditional) mind is of a non-analytical bent, which is very unfortunate, seeing that this mental attribute is more of a
limitation than anything else. Admittedly, there is a place for intuition and emotion in life. Life is not all logic. But this kind of point is often covertly taken as an excuse for being unmindful of logic and rational procedures generally; as if from the fact that life is not logic, it follows that it is not logic in any part at all (Wiredu 1980:11,12).

Wiredu is much less positive than Horton about African traditional healers and diviners. It does have its merits but:

Instead of a sober inquiry into the causes of disease whether of the mind or body or both, our medicine men launch into stories of malevolent witchcraft and necromancy. Meanwhile, both children and adults, the children in greater number, die or are incapacitated through the administration of scientifically unresearched prescriptions. In this situation any inclination to glorify the unanalytical cast of mind is not just retrograde; it is tragic (Wiredu 1980:12,13).

To change this approach into a habit of thinking which will make an African science not only possible, but a dynamic reality, is a need situated in education.

My suggestion is that, starting from fairly early stages, our education needs to be given a considerable methodological component. Our children should be initiated early in life into the discipline of formal and informal logic and into the methodology of rational thinking. ... What is wanted is a certain kind of training in methods, the kind of training that will produce minds eager and able to test claims and theories against observed facts and adjust beliefs to the evidence, minds capable of logical analysis and fully aware of the nature and value of exact measurement. Such a training is not only likely to discourage superstition; it would also tend to undermine that authoritarianism on which I commented earlier (Wiredu 1980:15,16).
J. Ndaba, an African philosopher from South Africa, is of the view that this can be done: 'The question may be asked if critical thinking can be taught. The answer is definitely "yes" even though the teaching of critical thinking does not involve the transmission of objective information' (Ndaba 1990:3).

Another African philosopher, John Murungi, says African students in philosophy and other sciences must not be uprooted from African traditions; he bears within himself the entire weight of what it is to be African, but the African is himself and not himself at the same time:

In this way the self-critical African may have kinship with Western counterparts if they are themselves self-critical. Being self-critical is not a monopoly of any individual, nation, or people. It is an inner calling in all men as men if only they will pay heed to themselves. It is a unitary inner call that links all humanity into one humanity (Murungi 1991:236).

An African science then would become possible by all means.

8 CONCLUSION

That African science is possible follows from all the argumentation up to this point. When we refer to 'Western' or 'African' these are meant as cultural terms. On the one hand, there is a common rationally in all human beings. Linked with this, there is the universal appeal of objective theoretical values like objectivity and critical distancing. On the other, cultural contexts in which science is embedded and grows, need not be detrimental to science. In fact, it generates and stimulates science. In this process, it heeds the appeal of universal theoretical values. It remains a mystery how a particular culture can give rise to a scientific practice, but eventually it becomes detached from that culture, and becomes something universal and objective. If the same could happen in Africa, an African science would result. There are, however, inhibiting forces that prevent just this. These can, however, be changed by education.
I think there is much in African culture and traditional thinking, that an African scientist can draw on and utilise in his/her science, an African science. Therefore Africa needs not to feel being left behind; it should rather experience this as a challenge. Likewise Westerners need not denigrate or even demonize Western science and technology, in spite of the wrongs of the colonial past. Instead it is something to be proud of. In a sense Western science is, speaking world-wide, indeed superior. This not because Western peoples are superior people, but because this science although generated in the West can be and is seen by humankind, be it Asian or African or European, as something universally human. For contingent reasons it was developed in Greek and Western Culture. Therefore African, Asian or Western science, are not three different sciences. It is the same science, the same game of science that is being played. However, science is not totally independent from its cultural roots and contexts. It has and can have particular acculturations and a cultural stamp. In this sense an African science is possible, indeed.

References


