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The Evolutionary Dynamics of Religious Systems
Laying the Foundations of a Network Model[1]

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This article aims at laying the foundations for the study of religions as systems, which would enable scholars to produce formalized and quantitative explanations and predictions about the inner causal structure and possible developmental tracks of religions. Whereas the notion of a 'system' has been formerly used in connection with culture and its various aspects (cultural systems, symbol systems, thought systems, belief systems, and even ritual- and religious systems), these accounts have not been based on a shared, formal, let alone mathematical, definition of systems and did not therefore provide scholars with appropriate tools to develop quantitative explanations and predictions about culture or religion.

Frustrated by the loose, metaphorical, and ultimately not very productive talk about 'systems' in cultural studies, skeptics have recently raised their voices against too easily presuming the existence of systems where there might be none. For example, Pascal Boyer (1994: 229) has written about the false "theologism" that takes the existence of connections among religious assumptions for granted. Benson Saler (2001; 2005 and personal communication) has argued that beliefs do not constitute a system, because there are apparently numerous beliefs that we can remove from the set of an individual's or culture's beliefs without affecting any other belief. Cognitive anthropologist Roy D'Andrade (2001: 252) suggested that culture is a collection of units, rather than an "entity." Cultural items in

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the minds of people do not constitute "a thing" because they are lacking "entitativity." D'Andrade compares this with the collection of items on his desk:

> [T]he collection of things on my desk doesn't really make much of a thing because the items on my desk aren't in immediate contact with each other, aren't made of the similar stuff, don't have much of a common fate, don't strongly resist dispersion, and don't interact strongly. Basically, the collection as a whole has no causal properties. […] In my opinion, the situation with respect to the entitativity of the collection of cultural items found in the minds of people living on Bali is not much better than that for the things on my desk [Clifford] Geertz's […] opinion of the matter notwithstanding.

D'Andrade's arguments raise interesting questions as to the extent to which one can compare a collection of items on one's desk with beliefs in an individual's mind, as well as about the systemic properties of both examples. But even scholars who did think about culture as a system, such as Clifford Geertz, whose ideas D'Andrade is criticizing in the passage quoted above, did not necessarily want to make quantitative, scientific predictions about culture or religion. Geertz, in spite of his own claims to the contrary, has been accused of rejecting anthropology as a scientific endeavor (Pals 2006: 285-287), and he famously claimed (Geertz 1973: 5) that cultural analysis is "not an experimental science in search of a law, but an interpretive one in search of meaning."

It has to be noticed, however, that not only scholars of culture and religion have been lacking a shared definition of systems. The problem is not that there have been no definitions around, but rather that there have been too many, and they were too diverse and too unconstrained (Backlund 2000). Among the many possible ways to discuss and analyze systems, I have chosen network theory, which has developed into an independent research field in recent years from mathematical graph theory, incorporating insights from the study of networks in a number of disciplines, such as chemistry, biology, ecology, sociology, economics, and computer science. This article will therefore introduce concepts that have not been used in cultural studies or religious studies traditionally, but we will keep the use of technical terms and mathematical notation to a minimum.

In the first part of the article, I will introduce the concept of systems and its exact mathematical definition in terms of graph theory. In the second part, I will consider the possible levels and angles of analysis that would allow us to create system theoretical models

of religion. Finally, I will give examples of how the dynamics of a religious system can be studied in the context of system theory.

1. Defining a system

Ludwig von Bertalanffy (1950: 143), the father of General System Theory, has given the following definition of a system: "A system can be defined as a complex of interacting elements […]. Interaction means that the elements stand in a certain relation, R, so that their behaviour in R is different from their behaviour in another relation, R'." Similar definitions have been proposed by other scholars. For example, according to J.G. Miller (quoted in Backlund 2000: 444), "a system is a set of interacting units with relationships among them." As Alexander Backlund (2000: 445) has recently pointed out, the problem with most definitions is that whereas they include some kind of systems, they exclude others, and do not exclude everything that is not a system. Consider a set of elements (*a*, *b*, *c*, *d*), where *a* interacts with *b* and *c* interacts with *d* (in the sense of Bertalanffy's definition). Do the four elements and the relations among them constitute a system? Since *a* and *b* are not affected by any of the other two elements (and vice versa), it might be perhaps better to speak of two systems instead of one in this case. And what shall we say about *a* and *b* if the behavior of *a* influences the behavior of *b* but not the other way around? We could answer the latter question by the clarification that interaction means a bidirectional relation, but this would not yet fix the previous problem. Shall we also require that every element of a system interacts with every other element? That would seem redundant: if *a* interacts with *b* and *b* with *c*, then an interaction between *a* and *c* is not needed any more (but rather emerges spontaneously). If we do require, however, that *a* interacts with *c*, the interactions do not have to be bidirectional any more: the three elements can influence each others' behavior in a chain-like manner ($a \rightarrow b \rightarrow c \rightarrow a$) and still constitute a system. The bottom line seems to be that relations within the system should allow for every element (potentially) affecting the behavior of every other element – but this again is a very imprecise definition that does not allow for any conclusions about how systems look like and how their elements are actually connected.

Instead of multiplying such clarifications, in this article we will proceed from a more compact and unambiguous, mathematical definition of systems that relies on the set-theoretical definition of Alexander Backlund (2000) and its graph-theoretical extension by Igor Gazdík (2007). Let us start by defining a couple of concepts that we will need for our

definition of systems: *set*, *relation*, *graph*, and *path*. (1) A *set* is a collection of objects. For example, the collection of objects on a desk mentioned in the previous section can be understood as a set. (2) As a next step, we can define *relations* among the elements of a set. For example, on the non-empty set $M = \{1, 2, 3\}$ we can define the relation "is greater than," which is a set containing the following ordered pairs: $R = \{(2, 1), (3, 1), (3, 2)\}$. In other words, an ordered pair (*a*, *b*) is an element of the relation *R* defined on the set *M*, if both *a* and *b* are elements of *M* and *a* is in relation with *b* (relation being "is greater than" in our example). (3) A relation defined on a set can be represented as a *graph*, provided that we are speaking of finite set. Graphs are mathematical objects consisting of *vertices* connected by *arcs* (or *edges*). The vertices of the graph in Figure 1 represent the elements of the set $M = \{1, 2, 3\}$ in our example, and the edges connect the ordered pairs that appear in the relation $R = \{(2, 1), (3, 1), (3, 2)\}$, pointing from the first element toward the second element of each ordered pair. In graph theory, edges that have a direction are called *directed edges*. (4) Finally, we can define the concept of *path* using another example. Imagine that the vertices in the graph are shops and the directed edges are one-ways streets connecting them. If we can drive from shop *a* to shop *b* (driving on any street only in the permitted direction) we can say that a path exists from *a* to *b*. In our example, there is a path from vertex 1 to vertices 2 and 3 as well as from vertex 2 to vertex 3. For the purposes of the present article we adopt Backlund's (2000: 448) definition with some simplification and define a *system* as follows. A system consists of a set, *M*, and relations on *M*, *R*. Two conditions have to be satisfied by *M* and *R*: (1) *M* contains at least 2 elements and (2) from every member of *M* there is a path to every other member of *M*. For example, if *a* influences the behavior of *b*, *b* influences the behavior of *c*, and *c* influences the behavior of *a*, then we can say that there is a path from *a* to *c* through *b*, a path from *b* to *a* through *c*, and a path from *c* to *a* through *b* (for a graphical representation see Fig. 2). The definition has the important implications that "[1] if an element affects parts of the system but is not affected by it, then it is outside the system, and [2] if an element is affected by parts of the system but does not affect any part of the system, then it is outside the system, too." For example, if elements *d* and *e* are added to the previous example (Fig. 3) so that the behavior of *d* influences the behavior of *a* (but *d* is not connected to any other element of the system) and the behavior of *b* influences the behavior of *e* (but *e* is not connected to any other element of the system), then neither *d* nor *e* belongs to the system. Applying the analogy that we have used above, if the vertices of the graph in Figure 2 were shops and the directed edges were one-way streets, it would be possible to reach the shops *a*, *b* and *c* from every other shop, but shop *d* could not be reached from any other shop and we

would be stuck once we have reached shop *e*. The graph represents a system only if every shop can be reached from every other shop.

Using graph theory, Igor Gazdík (2006) has extended Backlund's definition of systems. Graph theory can be used to analyze systems in many different ways, such as studying subsystems or identifying elements that are crucial to the functioning of the system. Vertices of a system can be connected by more than one edge, or edges can connect more than two elements (hypergraph), which helps to capture the complexity of interactions within a system. The concept of a graph is analogous, for our purposes, to the concept of a network (in that case we might speak of connected *nodes* rather than *vertices*). Modeling religious systems as graphs (or networks) will enable us to apply insights from graph theory (and network theory) to the study of religion: for example, we will be able to answer questions about the systemic nature of beliefs by employing such a method.

2. Religious systems

Now we can give a definition of a *religious system* – a simple one to start with. Let the system consist of two vertices, V_1="beliefs" and V_2="artifacts," connected by two edges, E_1 directed from V_1 to V_2 and E_2 directed from V_2 to V_1, as shown on Figure 4. This system is the simplest one possible: it contains the minimally required two vertices, and there is a path from any vertex to any other vertex. It involves bidirectional interaction between religious beliefs and artifacts: religious beliefs, such as beliefs about gods, spirits, objects, and places, facilitate the creation of artifacts, such as texts, objects, architecture, instruments, and performances. Artifacts, in turn, generate beliefs in the minds of people who use them. The interaction between beliefs and artifacts is somewhat similar to the interplay of internal and external (or private and public) representations described by Dan Sperber (1995: 77-97), but artifacts in this system do not need to represent (or stand for) beliefs in any direct way (and vice versa). Further, the concept of a religious system is often used in the sense of a "system of religious beliefs" (properly a set of religious beliefs) about gods, spirits and the like. The religious system under discussion is not to be interpreted as a system of beliefs that is secondarily manifested in pieces of religious art. All four components of the system, that is, artifacts, beliefs, and the two edges connecting them, are equally important, and after removing any of them the system would cease to exist. Numerous examples of how this system functions in practice can be mentioned from various religions. Consider European Reformation, where

changes in beliefs resulted in spectacular changes in the production and use of religious artifacts, including Church interiors, music, Bible translations, and literature. The new set of artifacts had a further effect on religious beliefs. Another example can be taken from Harvey Whitehouse's (1995) ethnography of the Pomio Kivung movement in Papua New Guinea, where the new ideas of the "splinter group" resulted in the construction of a new community building (the "round-house") in ancestral style, which then served as the spot of various dramatic events and the (trans-)formation of beliefs within the group.

There are three questions in particular that we will ask about our simple religious system in the rest of this section. (1) Is it meaningful to break down the system to further components? (2) Are there components that have to be added to the system? (3) Are there factors outside of the system that are relevant for its functioning? Let us start with the first question. (1) The plurals "artifacts" and "beliefs" already suggest that both of these components can be broken down into further components. Although our system remains functional if it contains only a single religious belief, practically it is hard to imagine any religious belief that would not be connected to several other religious beliefs. For example, believing that a person or object has supernatural qualities or powers implies many other beliefs about the origins, history, and possible future consequences of that quality. Such a belief is likely to be shared with other people, resulting in various artifacts, such as texts and pieces of art, which in turn generate similar religious beliefs in other people.

We can reasonably argue that at least some beliefs are connected to each other. In such a case, beliefs and connections between them can be represented as networks. A simple way to represent networks of beliefs is a word association network, where two words are connected if people associate them with each other. For example, if you enter "umbrella" into the online query form of the Edinburgh Word Association Thesaurus as a stimulus, the database will tell you that 60 percent of people associated it with "rain," 8 percent with "stand," 4 percent with "black," and so on, the total number of words associated with "umbrella" being 22. In terms of graph theory, "umbrella" is a node of the association network that is connected to 22 other nodes (in other words, it has a degree of 22). If you now enter "rain," you get 41 associated words, starting with "snow." You can again pick any of the 41 words and continue to explore the network. It is also possible to experiment with words connected to religion. The stimulus "religion," for example, will be associated with "God, Church, Christian, faith, Catholic, sex, belief, Bible, book, Church of England, Christianity, cross, Jesus, Jew," just to mention the top of a list of 43 items. More sophisticated networks that connect concepts include association networks that distinguish various types of

associations (such as synonyms and antonyms) and semantic networks, where concepts are connected by different kinds of relations such as "has" or "is a:" for example "parrot" in a semantic network is connected to "bird" by the relation "is a" and to "feather" by the relation "has:" a parrot "is a" bird and "has" feathers.

Does the fact that beliefs form networks mean that they also form systems or *a system*? Not necessarily. All systems can be represented as graphs (or hypergraphs), but not all graphs represent systems: for example, if we take away the edge between vertices *c* and *a* from the graph shown in Figure 1 (or turn around its direction), the resulting graph will not contain a system any more. It is easy to see that at least some beliefs affect the behavior of other beliefs. For example, priming the brain with one belief can facilitate the recall of another belief. Association networks can be mapped out by a similar procedure: after hearing or reading a word, associated words come to mind more easily than other (non-associated) words. A little more experimentation with the Edinburgh Word Association Thesaurus shows that the stimulus "God" yields the response "Christian" and vice versa. Both of these two vertices thus influence the behavior of the other vertex, and therefore they constitute a system. Is there a way to know whether the association network contains also larger subsystems, or whether the whole network forms *a system*? Given a set of data, this is an empirical question. There are different methods to analyze networks and gain insights about their components, of which I will give some examples in the final part of the article. Probably some of these methods could be adjusted to find systems that fulfill the definition given in the previous section – but unfortunately we have no ready-made tools that would give an immediate answer to the question. Recently Gergely Palla et al. (2007) have analyzed communities in directed association networks (Nelson et al. 1998), but they have excluded from their search cycles like {*a*, *b*, *c*} in Fig. 1. Yeon-Mu Choi and Hyun-Joo Kim (2007) have published an interesting study of directed connections among mythological figures in Greco-Roman mythology. Whereas this study reveals interesting facts about the network of mythological figures, the directions given to the edges is not very helpful in deciding on the systemic nature of beliefs (edges in Choi and Kim's study reflect cross-references between lexicon entries). It is likely that all beliefs belong to some larger, interconnected network (that is, they are connected at least to some other beliefs), and based on the samples that we have examined we can also hypothesize that they also form systems, many of which are probably connected into larger systems (suprasystems). Yet we cannot say with absolute certainty at this point that all religious beliefs in a religious system form a belief system or are parts of a belief system.

Also artifacts are more than just "collections" of items on a desk (referring again to D'Andrade's analogy). Some artifacts evidently form a system. The elements of any architectural construct are good examples: removing pillars from a cathedral will change the distribution of forces in the structure, eventually resulting in the collapse of the building. Even the much more modest round-house in Whitehouse's ethnography (1995: 13) is a system rather than a collection of components. We can, however, remove altars, organs, statues, and many other components from a cathedral, as indeed Reformation did, without affecting the building from the static point of view. One might object that the artifacts that we have removed change the function of the building: in order that it can be used for a Catholic mass, for example, it needs to have an altar. Yet in this case it is the religious system that changes, rather than the system of artifacts. Religious systems thus seem to contain subsystems of artifacts, but this includes artifacts that do not form a system among themselves. Some artifacts that are not parts of a system of artifacts still can be thought about as parts of a network of artifacts. Many of them are parts of particular configurations and cannot be found apart from that configuration normally. It can be said that networks of artifacts are often themselves "artificial," in the sense that their arrangement is not due to natural laws but cultural conventions. Thus networks of artifacts are themselves artifacts. Whereas in the brain beliefs are represented on a neural network that is determined by anatomic structures as well as by electric and chemical systems of communication, artifacts are not normally interconnected by such constraints and systems of communication. However, there are at least two important arguments for the view that the principles that underlie the organization of artifacts and beliefs, respectively, are not all too different from each other. First, the way networks of artifacts are formed and maintained in the framework of cultural systems is comparable to the creation and maintenance of belief systems. One may object that most artifacts belong to networks and systems only because beliefs in our minds establish such relations among them. It can be argued, however, that many beliefs as well as connections among them that are represented in our nervous system can only be maintained because a certain configuration of artifacts exists in our environment. We live in a cultural environment that provides our mental representations with indispensable scaffolding, without which many of the beliefs represented in our brains would diminish. Second, in (post-)industrial societies more and more artifacts also form physical networks and interact by using their own language of communication. The artifacts that surround us are becoming increasingly systemic. In sum, as was the case with beliefs, one may hypothesize that many artifacts belong to interconnected

networks, in a way that is quite comparable to the networks of beliefs, though certainly not all such networks are systems.

How can we include networks and systems of beliefs and artifacts in our initial model? Subsystems have to be connected to suprasystems by at least two edges (one directed from the subsystem toward the suprasystem and another one directed from the suprasystem toward the subsystem) in order to ensure that the behavior of the subsystem both influences the behavior of the suprasystem and is influenced by its behavior. For two networks to be connected, a single edge between them is sufficient. Networks and systems of beliefs and artifacts are obviously connected in complex ways. Various beliefs can be attached to various artifacts, irrespective of how those beliefs and artifacts are connected among themselves. A *random* example is shown in Figure 5 (the direction of edges among artifacts and the direction of edges among beliefs is ignored). Actual networks can be extremely complex, and cannot be analyzed without the assistance of specialized software. However, we might be able to make some general suggestions about networks based on empirical research that has been previously done in various fields.

(2) Our second question concerned the addition of further components to the system. Let us start with emotions, which have played an important role in recent cognitive theorizing about religion (e.g. Pyysiäinen 2003: 130-142). One possibility would be to add emotions as a further subsystem, which is connected both with artifacts and beliefs. It seems questionable, however, that emotions form a system or even a network in the technical sense, as the concept is used in this article. Another possibility is to add emotions to the system as a set of beliefs. This approach is supported by the fact that both beliefs and emotions are implemented in the brain – even though emotions are closely connected to the archaic brain and somatic processes (Ward 2006: 309-335). A third possibility is to think about emotions as processes that act on the components of the system. Emotions can result in the creation of beliefs as well as they strengthen or weaken, establish or delete links among beliefs and between beliefs and artifacts. To use a somewhat banal example, love creates links between the mental representation of the beloved one and mental representations of a number of pleasant things in the world. A fourth possibility is to include emotions both as processes and beliefs. The concept of mental representations of “pleasant things” in the previous suggestion requires that emotions are understood not only as processes but also as permanent (components of) mental representations. Without further discussing the problem at this point, I suggest that it is helpful to make a difference between emotions as processes (playing an important role in

rituals, which we will briefly discuss in the final part of the article) and lasting mental representations of emotions that can be regarded as parts of the network of beliefs.

So far we have discussed religious systems as networks of beliefs and artifacts. But one can object that religious systems in reality do not look like that: they rather consist of people acting and interacting in particular ways, performing rituals, and participating in different kinds of joint action. Evidently people hold beliefs – but whose beliefs are we interested in? Is it the beliefs of the priest or of the congregant that are included in the network? The religious system under discussion is a model that enables a particular representation of data in order to make it possible to gain insights about religion. Models are always limited in their scope, and so is our religious system. A major simplification involves the representation of types rather than of instances of beliefs. Network models used in scientific research typically have to make a choice between representing either types or instances (Santos et al. 2007). For example, mapping out the interactions of all animals living in a habitat is practically impossible: you might be able to follow a family of lions day and night, but hardly every single animal with which they interact. Ecological networks therefore include species (types) rather than single animals and plants (instances). Now consider the task of mapping out a terrorist network (e.g. Moon and Carley 2007). In that case, we want to know a social network of individual terrorists, that is, of instances. Association networks and semantic networks are dealing with types, mapping out an average version of beliefs that several individuals hold. Theoretically, we could also include different types of religious beliefs in a single system: for example, an "expert type" and a "lay type" could be defined where experts try to change the belief systems of lay people by interacting with them and a range of artifacts (such as religious texts). Such complex interactions could be studied with the help of computer modeling[2]. For the time being, however, we do not pursue the possibility of such models, and regard social networks as another dimension of the religious system.

In spite of the fact that social networks have been studied for decades, what they are and how we can measure them is far from being self-evident. In social networks, a link between two people is thought to exist if they interact with each other (with some regularity or in particular ways). Sometimes, however, we rather want to know what kind of beliefs people maintain about each other (e.g. when we draw a sociogram based on a questionnaire). In the

[2] Agent-based modeling is a computerized method to study such interactions. Whereas previously most agent-based modeling has focused on the interaction of agents having a simple cognitive architecture (capable of representing a small set of simple beliefs), recently more sophisticated models have been designed for example by Ron Sun (2006, 2007).

study of social networks, it is usual (Krackhardt 1987) to make sharp distinction between "cognitive" (the latter type) and "behavioral" networks (the former type). Whereas it is useful to make such a distinction in empirical research (e.g. Pittinsky and Carolan 2008), we have to recognize that "behavioral" networks are based on and closely related to "cognitive" networks. In fact, all social networks that are manifested in interactions among people materially exist as beliefs and artifacts: people hold particular beliefs about each other and typically they interact by means of artifacts. Whether two people interact with each other is largely determined by the beliefs they hold and/or the artifacts that make interaction possible, such as being friends or allies, living in the same street or village, etc. Social interactions, in turn, can result in the modification of beliefs and artifacts, such as making new friends or sending postcards. Most importantly for our purposes, social networks influence how beliefs are created and changed. Social networks have a number of features that allow us to make predictions about how beliefs will spread in a population, and whether they will disappear or survive in the long term. Also this feature of social networks is reciprocal: there are beliefs (also religious beliefs), that can directly influence the formation of edges in social networks. For example, if one follows Christianity and obeys Jesus' command to love one's neighbor as oneself (Matthew 21:39, based on Leviticus 19:18), this evidently leads to the creation of social ties that shape social networks in one's environment.

Finally, we can ask whether social networks related to religious systems form subgraphs (or subsystems) of social networks in general – in a similar way as religious artifacts and beliefs form subgraphs and subsystems of a cultural system (Fig. 4). It seems difficult to give a general answer to that question. In contemporary Western societies, religious communities can be relatively easily distinguished from other communities and the rest of society – but this is hardly the case in various traditional societies, where religion permeates all aspects of life. An ancient Greek city, for example, was simultaneously a political and a cultic community, and this also seems to be true for today's pre-industrial societies. A closer look at a Christian or Jewish congregation in a modern, secular state will also reveal that social relations outside of the domain of religion still very much influence the formation of a religious congregation and vice versa. It might be the case that social connections and networks related to religious systems are so tightly integrated into larger social networks that we cannot map out and separately study a subgraph or subsystem of social networks specific to religion.

(3) The third question that we have raised in this section concerns the role of external factors: are there factors outside of the system that are relevant for its functioning? (a) First,

religious beliefs are only a subset of all beliefs that we maintain and religious artifacts are only a subset of all artifacts people produce. We can hypothesize that a relation similar to the one found between religious beliefs and artifacts exists between beliefs and artifacts in general, and therefore a cultural system can be defined in a similar way as we define a religious system. We can further accept (without further analysis at this time) that religious systems influence the behavior of cultural systems and vice versa. In that case, we can say that a religious system is a subsystem of a cultural system. A system that interacts with another system that is not its subsystem is called an *open system* (Backlund 2000: 450). Religious systems are therefore open systems: they interact with cultural systems, which are not their subsystems. (b) Second, it is obvious that producing any artifact, even a humble arrow or stone tool, costs energy. Producing and maintaining networks and systems of artifacts (such as building and decorating a sanctuary) can be extremely costly. But also acquiring and maintaining beliefs is not without costs: the weight of the human brain makes up only two percent of the total body-weight, but the brain consumes twenty percent of the body's energy. Since a religious system can hardly generate the resources it needs (religious artifacts cannot produce energy, they cannot be eaten), resources must come from an external system, particularly from food production. Food production can be regarded as another subsystem of cultural systems. It is also probable that religious systems influence beliefs that also play a role in food production and vice versa (food taboos, gods and spirits connected with vegetation, influence on productivity etc.). Religious systems and food production are therefore two interconnected subsystems of cultural systems (Fig. 6).

4. Dynamics

Let us now add a temporal dimension to our study of religious systems. At any given point of time, the system can be described by describing its vertices and edges. We can examine, for example, how many vertices the system has, what kind of vertices they are (beliefs, artifacts, or their possible subcategories), how many edges each vertex has on average, how edges are distributed among vertices, and so on. Then the dynamics of the system can be defined as the change of such variables as a function of time. If we repeatedly examine a religious system as time goes on, we can expect to find that some new beliefs and artifacts are added to or removed from the system, and new relations among them appear or existing relations disappear. The dynamics of a religious system relies on the interactions that have been

outlined in the previous section. At the level of instances (from the viewpoint of the individual believer) the system is in perpetual motion: beliefs (mental representations) facilitate the production of artifacts (external representations) and artifacts generate beliefs. People are born and die, learn and forget, and make new artifacts, which can also perish with time. If we take a look at the dimension of social networks, we can see that connections may change all the time and nodes (individuals forming social networks) can be replaced. At the level of types, however, this might remain unnoticed, similarly as the fate of individual animals or plants does not normally change the overall picture of an ecological system: lions and antelopes die or migrate to new territories, yet the ecological system can remain unchanged. Such a view of the religious system corresponds to the observation that most real-life religions around us seem to operate in a fairly constant and continuous way, even on a historical time-scale.

How can we explain the seemingly unchanging character of religious systems around us? It has been suggested that religious beliefs occupy ideal or close to ideal positions in the space of possible beliefs, particularly due to their *minimally counterintuitive* structure (Boyer 1994: 48, 121; Boyer 2002; Barrett forthcoming) that makes them memorable as well as it allows the mind to make rich inferences from them. Following Dan Sperber's (1995) use of the system theoretical notion of "attraction," it has been suggested that religious beliefs occupy "attractor positions." One might suggest that if religious beliefs are (nearly) optimal beliefs, this will guarantee the stability of religious systems (cf. Sperber and Hirschfeld 2004). For the purposes of this article, we can ignore the debate that has developed around experimental findings about counterintuitive ideas (Boyer and Ramble 2001; Barrett and Nyhof 2001; Atran 2002: 100-107; Norenzayan and Atran 2004; Gonce et al. 2006; Upal et al. 2007), and accept that some form of counterintuitiveness does contribute to the memorability and stabilization of concepts. Would this guarantee the stability of religious systems? A comparison with ecological systems might be helpful at this point. All species that live on earth today evidently evolved to occupy some kind of optimal position in their environment: this follows, after all, from the mechanism of natural selection. This optimum, however, is relative to (a) the natural conditions of its habitat (such as climate and landscape; cf. Mayr 2001: 152-153), (b) the ecological system to which it belongs (e.g. it can optimally predate on some species and defend itself against other species), and (c) the options that were left open by its previous developmental history (e.g. being a fish, bird or mammal; cf. Mayr 2001: 140-143). Speaking of beliefs, their (assumed) optimality has been achieved relative to a similar set of constraints: (a') religious beliefs have developed in a natural habitat, which includes the natural environment and human anatomy; (b') they are part of an "ecological system,"

consisting of other elements of culture; and (c') finally, their development is determined by previous developmental stages (although cultural bits might change more freely and rapidly than do biological species; cf. Sperber 1995). Especially important for our purposes are the first and second criteria: if we assume that there are "attractor positions" toward which beliefs tend to develop, such positions are relative to cultural niches (consisting of natural environments and cultural systems). But in that case cultural niches cannot remain unchanged, since that would preclude the change of the species that constitute them. The behavior of each part in the system influences (to different degrees) the behavior of the whole system and therefore the behavior of every other part of the system. In other words, both ecological and cultural systems display complex behaviors, which cannot be obviously understood from the properties of their parts (Nicolis and Prigogine 1989; Chu et al. 2003; Mainzer 2004)[3] We cannot go into more details about cultural complexity at this place (Denton 2004; Czachesz 2007), but have to notice that most real-life systems are complex systems.

We will therefore consider the problem of stability and change from the perspective of the study of complex systems, which will also provide us with clues about the expected changes and possible evolutionary trajectories of religious systems. There are three different kinds of states in which systems can remain for a longer period of time (Nicolis and Prigogine 1989: 66). The first one, mechanical equilibrium, is only possible in so-called *conservative systems*, which preserve their total energy, translational momentum, and angular momentum (Nicolis and Prigogine 1989: 46-50). An example of a conservative system is a pendulum operating under the idealized conditions of classical mechanics, which ignore friction. A pendulum has two equilibrium states: an unstable equilibrium at the highest point of its path and a stable equilibrium at the lowest point. The pendulum can rest at its stable equilibrium or move periodically without any change as long as it is left alone. If its motion is disturbed, it will stop or switch to a different amplitude (ignoring the case of an "overdamped" system). If a religious system were conservative, we would be able to observe an endless generation of beliefs from artifacts and vice versa. This would, however, require that it remains uninfluenced by its (cultural and natural) environment. As soon as the slightest influence from the environment occurred, however, the system would not be able to return to its previous state. Such a religious system would be completely at the mercy of its environment. Since the environment inevitably impacts religious systems all the time (as Figure 6 shows), if their

[3] Using a more precise mathematical language, these complex systems are analogous to non-linear systems, the behavior of which cannot be understood as a linear sum of the behavior of their parts.

dynamics were analogous to the dynamics of conservative systems their behavior would be constantly and directly reflecting changes in their environment.

Most real-life systems are *dissipative* (Nicolis and Prigogine 1989: 50-54): for example, friction is part of real mechanical systems. A dissipative system can be an isolated system, one that does not exchange matter or energy with its environment. Such a system will irreversibly evolve toward a second type of stability, the final state of thermodynamic equilibrium, in which parts of a system have achieved their maximum level of disorder. Religions do not seem to be in such a state. Again, we can refer to Figure 6, which shows that our religious system is interacting with a complex environment. Religious systems are therefore best studied as dissipative, non-isolated (or open) systems. Such systems can exchange matter and energy with their environment, and have two kinds of stable states. The first option is to reach a thermodynamic equilibrium (our second type of continuous state; see above), in which the system stops exchanging energy or matter with its environment, similarly as an object that has reached the temperature of its environment and stops exchanging heat with it. Using the notion of thermodynamic equilibrium analogically, rather than in a technical sense, we can imagine that a religious system is in equilibrium with its cultural environment in some ways. A religious system might, for example, share the belief system of its cultural environment and vice versa. Differences in beliefs between religion and the rest of the cultural system have not been much of a concern, by-and-large, until the arrival of modernity. In contemporary Western theology, in contrast, an exchange of ideas with science, different worldviews, and cultural theories is a major source of the dynamics of the belief system of religion. To take another example, a medieval monastery might have been independent to a large degree from its cultural (but not its natural) environment in terms of food and material needs. Yet such examples are very limited both in extent (e.g. monks did depend on artisans, building materials, supply of novices) and scope (e.g. monasteries interacted with culture and the rest of the religious system in many ways). The notion of thermodynamic equilibrium in open systems is thus also of limited use to understand stability in religious systems.

Another option for dissipative, non-isolated systems to acquire stability for some time is to be in a *stationary non-equilibrium state* (the third type of continuous state in our discussion). In such a state, the system *does exchange* matter or energy with its environment, but its internal and external parameters are related in such a way that the system enjoys some level of stability. If matter on Earth were in a chemical equilibrium (which is a component of thermodynamic equilibrium), for example, 99 percent of its atmosphere would consist of carbon dioxide and the salt content of its oceans would be 13 percent – the current figures

being 0.03 percent and 3.5 percent, respectively (Lovelock 1979). The biosphere of Earth, like many real-world systems, operates far from thermodynamic equilibrium: the influx of energy from without the system (from Sun) makes the persistence of such a non-equilibrium state possible. The biosphere has reached its current state through a long process of complex self-organization (balancing myriads of interdependent effects). Now we can apply this model to human culture, which has gone through another amazing process of self-organizing, in which mental processes and artifact production can be seen as two major factors. Religion occupies an interesting position within culture, because of its continuous existence in the midst of cultural change. How can we explain this continuity and how can we account for change in religious systems?

Religious systems are complex, self-organized systems, rather than engineered systems with a straightforward structure and easily detectable subsystems (modules) that have clearly distinguished functions. It seems reasonable to think that culture has developed similarly as did biological and ecological systems, that is, through a long history of evolutionary "tinkering," reusing existing bits and pieces and adding new ones, often resulting in redundancy or seemingly dysfunctional units. It is questionable if parts of culture – such as religion – can be rightly called "spandrels" (Gould and Lewontin 1979; Atran 2002: 43-45). Spandrels (ornaments filling up space in gothic architecture) are clearly *not* part of the system of gothic architecture from the static point of view: they are connected to the system by outgoing edges (they exert gravitational force on some elements around them) but do not have incoming links (gravitational forces are not distributed to them). Religious systems, in contrast, are parts of cultural systems, connected to them by both incoming and outgoing edges. (It has to be noticed that although spandrels are not parts of the static system of buildings, they are certainly parts of the cultural system of medieval culture.) What we think about the adaptiveness or evolutionary path of religion is a completely different matter: naturally developed subsystems may contain some level of redundancy (possibly serving as backup systems, as it were) or their function might remain largely hidden, due to the complexity of the system, including unclear boundaries between modules and circular interactions among individual parts and the whole system.

In sum, religious systems can be thought about as subsystems of culture that inhabit particular niches of cultural landscapes. Its remarkable continuity through history in the midst of cultural change does not mean it is in an equilibrium state, but can be rather characterized as a stationary non-equilibrium state (that is, a state not showing radical changes on a given timescale). Yet such states are never actually steady. In real-life contexts, the environment

communicates matter, momentum, or energy to a system all the time – in cultural systems we might consider such influences at a more abstract level –, and it is practically impossible to control for every state variable of the system with unlimited precision. (State variables such as temperature or pressure can be used to characterize states of thermodynamic systems; for cultural and religious systems other variables have to be identified.) Also, quite independently from the environment, complex systems all the time exhibit small deviations from the reference state (called *fluctuations* or *background noise*). The continuous state (or reference state) of a system can be therefore interpreted as the most probable state within a range of continuous *perturbations* (that is, local, small-scale changes). There are various possible reactions of a system in response to perturbations (Nicolis and Prigogine 1989: 66-71), of which we only mention a few important options at this place. Sometimes the system remains all the time in a given vicinity of a continuous state. In other cases, perturbations initiate a sequence of states, through which the systems returns to the reference state (orbital stability). It is also possible that in reaction to perturbations the system steadily approaches a reference state (asymptotic stability), which in such a case can be called an *attractor*. Attractors can be local, when the system returns to the reference state only if the perturbation is below a certain limit, or they can be global, when the system will return to the attractor after any perturbation, regardless of its size. Finally, perturbations might grow rapidly and drive that system away from the reference state (which is then called and unstable reference state).

If we apply these different classes of system behaviors to religious systems, we gain a new perspective on continuity and innovation. Whereas perturbations in engineered systems are normally negative, undesirable effects, in self-organized systems they are essential for the development of the system. Cultural stability is desirable for a certain amount time, but being bound by an attractor forever would be detrimental for human culture, since it would prevent us from experimentation. In such a case the only way to facilitate cultural change would be radical impulses from the environment – such as a major climate change –, for which we would be then completely unprepared. It seems that human culture is staying near to reference states with considerable perturbations, which occasionally result in abandoning the old reference state and the emergence of a new reference state (such as major historical transitions).

Within this general framework, religion seems to occupy a special position. In spite of the major cultural transitions of European culture in the last two millennia, the two major religions within this culture, Judaism and Christianity, have remained almost unchanged since antiquity. We have already rejected the idea that the assumed stability of religious beliefs

could be responsible for the stability of religions. Can we perhaps adopt a milder form of this hypothesis? In spite of the great variety of cultures, there is a good deal of cross-cultural agreement among religious beliefs. It seems indeed reasonable to think that cross-cultural factors such as anatomy or the natural environment will drive the evolution of beliefs or components of beliefs toward some attractor positions. Artifacts are no exceptions: anatomy, purpose, and environmental constrains define attractor positions for their development. This does not mean, however, that all beliefs and tools globally end up in the same attractor positions. The evolution of beliefs and artifacts, as well as of cultural or religious systems in general, is constrained by their history (similarly as we have noticed about biological evolution). Once you have a tool, options for further improvement are restricted by its current shape. Another, somewhat related, issue is the effect of local attractors. Local attractors might "trap" a system if perturbations practically never achieve a level at which the system would not return to its reference state anymore but would start to migrate toward another attractor, preventing the system from arriving at a new reference state, which might be more advantageous from some perspective. Of course such a concept already presupposes that we have criteria for prioritizing various states of a system. In the case of cultural systems one can think of some ideologically set preferences, such as cultures favoring social justice or individual freedom, but there are also more general criteria, such as stability or evolvability (the capacity of finding better attractors).

Modeling religious systems as networks allows us to study stability and change in them with the help of parameters that describe networks. At this point we can only give some tentative examples, but mapping out the networks with the help of computerized tools will enable us to make quantitative measurements and predictions. In our religious system, beliefs constantly generate artifacts and artifacts generate and modify beliefs. Rituals, to which we have paid little attention in this article, obviously play an important role in this process. They can be introduced to the network model as *hyperedges*, that is, edges that connect more than two vertices (beliefs or artifacts). Rituals may rearrange edges in the religious system, influencing beliefs, artifacts, or social networks. If we assign weights to the edges (in our imaginary network connecting shops this would comparable to streets having different number of lanes), we can think of changes that involve the weakening or strengthening of connections. Since rituals are themselves represented in the religious system as beliefs and artifacts, rituals can also modify rituals. It is to be expected that such interactions occur within the system in ways that maintain the stability of the system in the midst of environmental influences. For example, aging is compensated by transmitting beliefs to a new generation of

believers; events that negatively or positively affect the community are interpreted in ways that help to maintain the belief system (e.g. attributing changes in the environment to benign or hostile gods and spirits). It is also obvious that the religious system will show perturbations due to internal and external factors. For example, environmental affects will be changing and beliefs will have a natural tendency to fluctuate. At this point, the system will follow one of the developmental trajectories that we have described in the case of thermodynamic systems, ultimately either remaining in the neighborhood of its previous, continuous state, or migrating toward a new one.

Modeling religious systems as graphs provides us with possibilities to make observations and predictions about their evolution. Graph theory and the study of real-life networks in various disciplines (as mentioned in the introduction of this article) have established various regularities with respect to how networks behave across different domains. Quite interestingly, observations about networks in one domain often prove themselves to be relevant for another domain: graphs are capable of modeling the organization of things in a fairly universal way. Let us take the concept of the *diameter* of a graph, which is defined as the maximum of the shortest paths between any two vertices in the graph (Berge 1973: 66): for any two vertices in the graph, we calculate the length of the shortest path between them (that is, their distance); then, the diameter is the length of longest of these shortest paths, which gives the distance of the farthest two points in the graph. A famous example of the practical application of this concept is the hypothesis of "six degrees of separation," which is a more precise formulation of the commonplace that we are living in a "small world." It was not a sociologist, but Hungarian writer Frigyes Karinthy (1929) who first suggested that any two humans on Earth are connected by not more than *five* acquaintances. Three decades later, Stanley Milgram (1967) formulated the idea of "six degrees of separation" as a scientific hypothesis and successfully demonstrated its truth in an experiment conducted in the United States. Networks that have a small diameter are called "small world" networks, and one of their important characteristics is that information spreads in them rapidly (Watts and Strogatz 1998). If religious systems are "small worlds," fluctuations can spread quickly in them, and fluctuations initiated at various points of the system can combine in unpredictable ways. A similar prediction can be made about social networks that are connected to religious systems: if they are small worlds, new beliefs can spread on them rapidly. At some stages of development, religious systems indeed show rapid change, whereas most of the time they do not: above we have made the observation that religious systems show relative stability in the midst of cultural and environmental change. This suggests that the network structure of

religious systems is changing from time to time, regulating the system's capacity of change (or evolvability). Of course diameter (or the empirically more accessible average shortest path) is not the only variable that is responsible for the spread of information in a network – but the investigation of those factors has to be postponed to future contributions.

Works cited

Atran, Scott, *In Gods We Trust: The Evolutionary Landscape of Religion*. Oxford: Oxford University Press, 2002.

Backlund, Alexander, "The definition of system," *Kybernetes*, 29 (4), 2000: 444-451.

Barabási, Albert-László, *Linked: How Everything is Connected to Everything Else and What It Means for Business, Science, and Everyday Life*. New York: Plume, 2003.

Barrett, Justin L., "Coding and Quantifying Counterintuitiveness: Theoretical and Methodological Reflections," forthcoming.

Barrett Justin L. and Melanie A. Nyhof, "Spreading Non-natural Concepts: The Role of Intuitive Conceptual Structures in Memory and Transmission of Cultural Materials," *Journal of Cognition and Culture* 1 (2001), 69-100.

Bertalanffy, Ludwig von, "An Outline of General System Theory," *The British Journal for the Philosophy of Science* 1 (2), 1950: 134-165.

Boyer, Pascal, *The Naturalness of Religious Ideas: A Cognitive Theory of Religion*. Berkeley: University of California Press, 1994.

Boyer, Pascal, *Religion Explained: The Human Instincts that Fashion Gods, Spirits and Ancestors*. New York: Basic Books, 2001.

Boyer Pascal and Charles Ramble, "Cognitive Templates for Religious Concepts: Cross-cultural Evidence for Recall of Counter-intuitive Representations," *Cognitive Science* 25, 2001: 535-564.

CFinder, The Cluster (Community) Finding Programme, Department of Biological Physics, Eötvös University (Budapest), www.cfinder.com

Choi, Yeon-Mu and Hyun-Joo Kim, "A directed network of Greek and Roman mythology," *Physica A* 382 (2007) 665-671.

Chu, Dominique et al., "Theories of Complexity: Common Denominators of Complex Systems," *Complexity* 8 (3), 2003: 19-30.

Czachesz, István,"Theory Forming in Biblical Studies: Contributions to an Interdisciplinary Dialogue," in: *Complexity. Interdisciplinary Communications 2006/2007*, edited by W. Østreng, pp. 55-58. Oslo: Center for Advanced Study, 2007.

D'Andrade, Roy, "A Cognitivist's View of the Units Debate in Cultural Anthropology," *Cross-Cultural Research* 35 (2), 2001, 242-257.

Denton, Trevor, "Cultural Complexity Revisited," *Cross-Cultural Research* 38, 2004: 3-26.

Dorogovtsev, Sergei N. and J.F.F. Mendes, *Evolution of Networks: From Biological Nets to the Internet and WWW*. Oxford: Oxford University Press, 2003.

Edinburgh Word Association Thesaurus, http://www.eat.rl.ac.uk/

Gazdík, Igor, "Modelling systems by hypergraphs," *Kybernetes* 35 (9), 2006: 1369-1381.

Geertz, Clifford, "Thick Description: Toward an Interpretive Theory of Culture," in C. Geertz, *The Interpretation of Cultures: Selected Essays*. New York: Basic Books, 1973.

Gonce, Lauren O. et al. "Role of Context in the Recall of Counterintuitive Concepts," *Journal of Cognition and Culture* 6, 2006: 521-547.

Gould, Stephen J. and Richard C. Lewontin, "The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme," *Proceedings of the Royal Society of London*, Series B, Biological Sciences, 205 (1161), 1979: 581-598.

Jablonka Eva and Marion J. Lamb, *Evolution in four dimensions: Genetic, epigenetic, behavioral, and symbolic variation in the history of life*. Cambridge, Mass.: MIT Press, 2005.

Jablonka Eva and Marion J. Lamb, "Précis of Evolution in Four Dimensions," *Behavioral and Brain Sciences* 30, 2007: 353-392.

Karinthy, Frigyes, "Láncszemek," in idem, *Mindenki másképpen van*, pp. 85-90. Budapest: Atheneum, 1929.

Krackhardt, D., "Cognitive social structures," *Social Networks* 9, 1987: 109-134.

Mayr, Ernst, *What Evolution Is*. New York: Basic Books, 2001.

Milgram, Stanley, "The Small-World Problem," *Psychology Today* 1, 1967:60-67.

Moon, Il-Chul and Kathleen M. Carley, "Modeling and Simulating Terrorist Networks in Social and Geospatial Dimensions," *IEEE Intelligent Systems* 22 (5), 2007: 40-49.

Mainzer, Klaus, *Thinking in Complexity: The Computational Dynamics of Matter, Mind, and Mankind*. Berlin: Springer 2004 (fourth edition).

McCauley, Robert N. and E. Thomas Lawson, , *Bringing Ritual to Mind: Psychological Foundations of Cultural Forms*. Cambridge: Cambridge University Press, 2002.

Nelson, Douglas L. et al., *The University of South Florida word association, rhyme, and word fragment norms*. http://www.usf.edu/FreeAssociation/, 1998.

Nicolis, Grégoire and Ilya Prigogine, *Exploring complexity: An Introduction*. New York: W.H. Freeman, 1989.

Norenzayan, Ara and Scott Atran, "Cognitive and Emotional Processes in the Cultural Transmission of Natural and Nonnatural Beliefs," in: *The Psychological Foundations of Culture*, edited by M. Schaller & C.S. Crandall, pp. 149-169. Mahwah, NJ: Lawrence Erlbaum Associates, 2004.

Palla, Gergely et al., "Uncovering the overlapping community structure of complex networks in nature and society," Nature 435, 2005: 814-818.

Palla, Gergely et al., "Directed network modules," *New Journal of Physics* 9 (6), 2007: 186.

Pals, Daniel, *Eight Theories of Religion*. New York: Oxford University Press, 2006.

Pittinsky, Matthew and Brian V. Carolan, "Behavioral versus cognitive classroom friendship networks: Do teacher perceptions agree with student reports?" *Social Psychology of Education* 11, 2008: 133-147.

Pyysiäinen, Ilkka, *How Religion Works: Towards a New Cognitive Science of Religion*. Leiden: Brill, 2003.

Saler, Benson, "On what we may Believe about Beliefs," in: *Religion in Mind*, edited by Jensine Andresen, pp. 47-69. Cambridge; Ithaca, NY: Snow Lion Publications; Cambridge Univ Press, 2001.

Saler, Benson, "Finding Wayú Religion," *Historical Reflections/Reflexions Historiques* 31 (2), 2005: 255-270.

Santos, Francisco C. et al., "Networks Regulating Networks: The Effects of Constraints on Topological Evolution," in *Proceedings of the Ninth European Conference on Artificial Life (ECAL 2007)*, edited by F. Almeida e Costa et al., pp. 956-965. *Lecture Notes in Computer Science*, LNAI 4648, 2007.

Sperber, Dan and Lawrence A. Hirschfeld, "The cognitive foundations of cultural stability and diversity," *Trends in Cognitive Sciences* 8 (1), 2004: 40-46.

Sun, Ron, ed., *Cognition and Multi-Agent Interaction: From Cognitive Modeling to Social Simulation*. Cambridge: Cambridge University Press, 2006.

Sun, Ron, "Cognitive Social Simulation Incorporating Cognitive Architectures," *IEEE Intelligent Systems* 22 (5), 2007: 33-39.

Upal, M.Afzal et al., "Contextualizing Counterintuitiveness: How Context Affects Comprehension and Memorability of Counterintuitive Concepts," *Cognitive Science* 31, 2007: 415-439.

Ward, Jamie, *The Student's Guide to Cognitive Neuroscience*. Hove, UK: Psychology Press, 2006.

Watts, Duncan J. and Steven H. Strogatz, "Collective Dynamics of 'Small-World' Networks," *Nature* 393, 1998: 440-442.

Whitehouse, Harvey, *Inside the Cult: Religious Innovation and Transmission in Papua New Guinea*. Oxford: Clarendon Press, 1995.

Whitehouse, Harvey, *Modes of Religiosity: A Cognitive Theory of Religious Transmission*. Walnut Creek / Lanham: AltaMira Press, 2004.

Figures

Fig. 1 Graph representing the relation $R = \{(2, 1), (3, 1), (3, 2)\}$ on set $M = \{1, 2, 3\}$

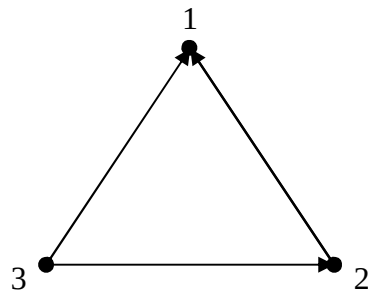

Fig. 2 Graph representing a system

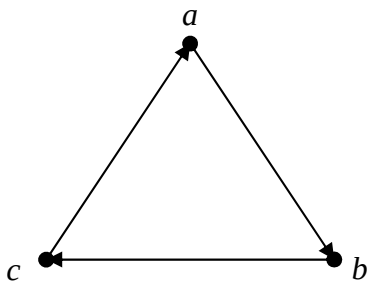

Fig. 3 Vertices *d* and *e* are not parts of the system

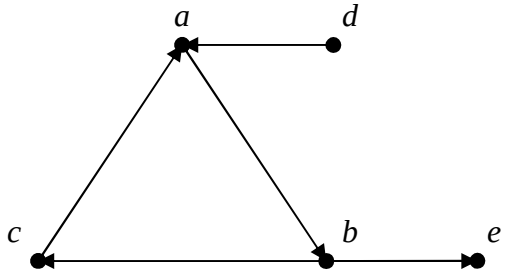

Fig. 4 The simplest (religious) system

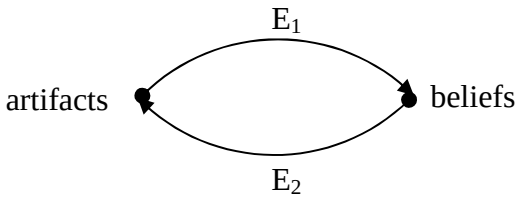

Fig. 5 Random example of beliefs and artifacts

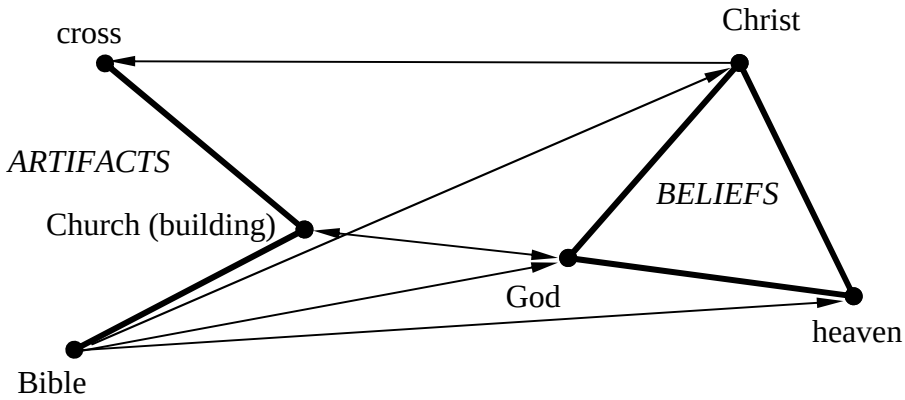

Fig. 6 Religious and cultural systems