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5. Ron Eglash - Africa in the Origins of Binary Code

"The relationship between what we do as physicists today and the future that our work engenders is dialogical in the sense that not only do our present actions determine what our future will be, but we must be ever mindful of the impact of our present actions on the future... Through our moral responsibility and awareness of signals and trends, we in effect, 'listen' to what the future has to tell us." (Donnell Walton, Chair, National Conference of Black Physics Students 1995.)

While the temporal traditions of African societies were frequently cited by colonialists as evidence for primitive superstition, they appear today in quite the opposite context: mathematical analyses of traditional African designs, techniques and knowledge systems indicate a wide array of sophisticated indigenous inventions. Like Paul Gilroy's fractal Atlantic, Donnell Walton's invocation of African divination traditions- of listening to the future- is not only useful in its call for greater ethical responsibility, but also as a reminder fo the surprising links between traditional

swarm 1

1. Nick Land-[Meltdown](#)
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digital hyperstition

1. Ccru- [Barker Speaks](#)
2. Melanie Newton-[Y2Panik](#)
3. Steve Goodman- [Hyper-C: Breaking the Net](#)
4. Ron Eglash - [Recursive Numeric Sequences in Africa](#)
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knowledge and modern science.

The modern binary code, essential to every digital circuit from alarm locks to super computers, was first introduced by Leibniz around 1670.

Leibniz has been inspired by the binary-based 'logic machine' of Raymond Lull, which was in turn inspired by the alchemists' divination practice of geomancy (Skinner 1980). But geomancy is clearly not of European origin. It was first introduced there by Hugo of Santalla in twelfth century Spain and Islamic scholars had been using it in North Africa since at least the 9th century, where it was first documented in written records by the Jewish writer Aran ben Joseph.

Geomancy is traditionally practiced by drawing patterns in the sand. It begins with four sets of random dashed lines. These are paired off (i.e. summed by addition modulo two), and the even/odd results recorded with two strokes or one stroke. Four of these binary digits represents one of 16 possible divination archetypes (ruler, travel, desire, etc.) Although the first four are generated by this random process, the following 12 are created by recursively applying the same pairing operation on the binary digits making up the four symbols (a process which can be seen in many other areas of African knowledge systems, c.f. Eglash 1995).

The nearly identical system of divination in West Africa associated with Fa and Ifa was first noted by Trautman (1939), but he assumed that geomancy originated in Arabic society, where it is known as ilm alraml ("the science of sand"). The mathematical basis of geomancy is however, strikingly out of place in non-African systems. Like other linguistic codes, number bases tend to have an extremely long historical persistence. The ancient Greeks held 10 to be the most sacred of all numbers; the Kabbalah's Ayin Sof emanates by 10 Sefirot and the Christian west counts on its "Hindu- Arabic" decimal notation.

In ancient Egypt, on the other hand, base 2 calculation was ubiquitous, even for multiplication and division, and Zaslavsky (1973) notes archeological evidence linking it to the use of doubling in the counting systems of sub-Saharan Africa. Kautzsch (1912) notes that both Diodorus Siculus and Oblian reported that the ancient Egyptian priests "employed an image of truth cut in halves."

Doubling is a frequent theme in African divination and many other African knowledge systems, connecting the sacredness of twins, spirit doubles, and double vision with material objects, like the blacksmith's twin bellows and the double iron hoe given in bridewealth. In a recent interview in *Wired*, Brian Eno claimed that the problem with computers is that they "don't have enough African in them". Eno was, no doubt, trying to be complimentary, saying that adaptive rhythm and flexibility is a valuable attribute of African culture. But in doing so he obscured the cultural origins of digital computing, and did an injustice to the very concept he was trying to convey. Take, for example, Henry Louis Gates' (1988, pp. 30) use of a recursive doubling description when discussing the relations between divination and sexuality in West African traditions:

The Fon and Yoruba escape the Western cersion of discursive sexism throught he action of doubling the double; the number 4 and its multiples are sacred in Yoruba metaphysics. Esu's two sides "disclose a hidden wholeness," rather than closing off unity, through the opposition, they signify the passage from one to the other as sections of a subsumed whole.

The binary coding of traditional African knowledge systems, like that of their antecedents in modern computing networks, is neither rigid nor arhythmic; its beat is a heritage heard by those who listen to the future.

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Paper delivered at “Realities Re-viewed/Revealed:

Divination in Sub-Saharan Africa.”

National Museum of Ethnology, Leiden. July 4-5.

An Ethnomathematics Comparison of African and Native American Divination Systems

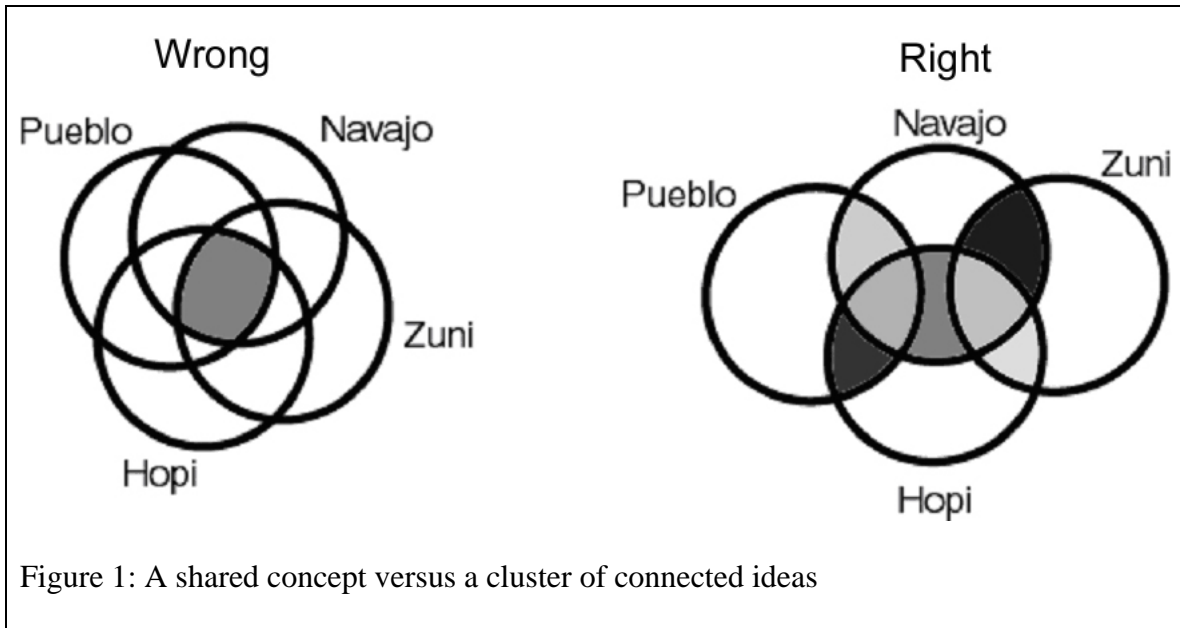
Abstract

Many material and conceptual aspects of Native American cultures are connected to randomness: gambling games, random events in trickster stories, and diversity in crop genetics all share some version of this theme. The presence of random movement in several Native American divination practices fits well into this portrait. Several forms of African divination, on the other hand, are better characterized in terms of “deterministic chaos” in the sense of nonlinear dynamics, and provide a similar fit to their cultural contexts.

The thesis of this paper is that many Native American cultures share a cluster of connected ideas around themes of randomness, and that many African cultures share a cluster of connected ideas around themes of deterministic chaos. The idea that African cultures are connected to deterministic chaos and its mathematical relatives in fractals and complexity theory are described in detail in Eglash (1999), but I will briefly review the essential concepts later in this essay. Let me begin however with Native American culture, since the idea of randomness is more familiar to most audiences.

1. Randomness as a cultural theme in Native American societies

By “Native American” I am only referring to indigenous cultures of North America, which were band and tribal societies, not the indigenous cultures of Latin America or South America. Even with that restriction, there is enormous diversity among these many cultures, and I do not mean to imply that they can be reduced to a single characteristic. By “cluster of connected ideas” I mean a network of mutually intersecting concepts



(figure 1). Not every culture will have every characteristic – for example of four features A, B, C, and D we might find A, B, C among the Zuni, B, C, D among the Hopi, etc. This is similar to Wittgenstein’s concept of a family resemblance: when we see a photo of a family we can say we see their “relatedness” even though there is no single feature that all of them have in common.

A. Diversity in Crop Genetics

Gary Nabhan, an agricultural researcher who works with Native American growers, notes

that sustaining genetic diversity was an important theme in indigenous knowledge systems. In searching for greater crop variety, Nabhan found that those areas with the strongest focus on ceremonial religious practices were also those with the greatest diversity in genetic resources. A variety of sunflower, for example, was propagated because it was used to create yellow face paint; although it was inedible it was interbreeding with edible varieties, increasing their genetic repertoire. Even outside of these ceremonial settings, Native American farmers still cited the religious framework as their reason for maintaining genetic diversity:

On one occasion, I asked a Hopi woman at Munqapi if she selected only the biggest corn kernels of all one color for planting her blue maize. She snapped back at me, "It is not a good habit to be too picky... we have been given this corn -- small seeds, fat seeds, misshapen seeds -- all of them. It would show that we are not thankful for what we have received if we plant just certain ones and not others" (Nabham 1983 pp. 7)

Corn is a particularly good example because it is easy to see the contrast between the single variety of yellow corn commonly consumed, and the diverse varieties of "Indian corn" that are typically used for decorative purposes in the fall (figure 2).

Why should Native American religions have such a strong emphasis on maintaining a more complex set of genetic resources? From a biological point of view, these turn out to be crucial for coping with environmental uncertainty. The winter ceremony bean has strong resistance against root knot nematodes -- not a typical problem, but in years with a nematode epidemic it could be the key to survival. Thus we can think of the emphasis on randomness in genetic resources as matching the randomness of Nature.

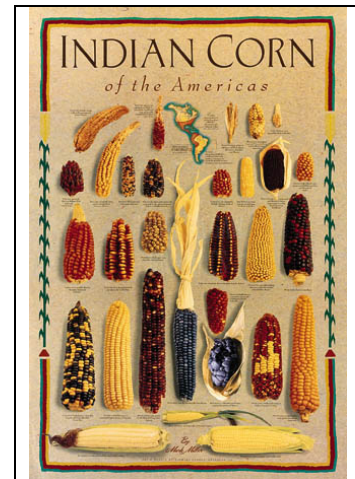


Figure 2: Varieties of Native American corn

B. Nature as Trickster

This systematic relation between complexity and uncertainty was not restricted to plant and animal genetics. Native Americans also made a similar correspondence in the myths of the creator/trickster, Coyote, as we see in the Navajo story of creation:

First Man, First Woman, and Coyote... were not satisfied with the sky. ...So they searched for glittering stones and found some mica dust. First Man placed the Star Which Does Not Move [polaris] at the top of the heavens. ...Then he placed the four bright stars at the four quarters of the sky. ...Then in a hurry, Coyote scattered the remaining mica dust so it did not fall into exact patterns but scattered the sky with irregular patterns of brilliance (Burland 1968 pp. 93).

While Coyote is creating randomness, tossing bits of rock into the sky, people are creating order; a four-fold symmetry of stars.¹ This juxtaposition of culture as order and nature as random is repeated in other trickster stories. In the mountains of Idaho, for example, the Shoshoni tell the story of how Coyote put salmon in the river by breaking a basket, again contrasting the ordered basket against the random cascade of fish spilling into the water. This stochastic randomness stands in contrast to the deterministic chaos of certain African tricksters, as we will see in another section of this paper.

C. Native American games of chance

Games of chance were extraordinarily popular in traditional Native American societies, particularly in connection with gambling. Randomness in such cases was not merely conceived in terms of chance. Ascher (1990 p. 93) describes a vivid illustration in the

Native American game of Dish. In the Cayuga version of the game six peach stones, blackened on one side, are tossed and the total numbers landing black side or brown side recorded as the outcome. The traditional Cayuga point scores for each outcome are (rounded to whole numbers) proportionate to the exact values calculated by probability theory (figure 3).

Combination B=Burnt side up N=Normal side up	Probability	Points assigned in inverse proportion to probability	Cayuga game points
6N	1/64	5	5
5N and 1B	6/64	5/6 (six times more likely)	1 (5/6 rounded to nearest integer)
4N and 2B	15/64	5/15	0
3N and 3B	20/64	5/20	0
2N and 4B	15/64	5/15	0
1N and 5B	6/64	5/6	1
6N	1/64	5	5

Figure 3: probabilities for outcomes and associated point scores.

There is no evidence for a Native American Pascal first calculating these probability distributions; it is far more likely that that in the thousands of repeated plays, such games gradually “evolve” the correct payoffs. Westerners are likely to conclude that such information does not deserve the status of “knowledge” because it lacks intentionality. But intentionality itself is culturally defined: in the Western tradition we expect a particular invention to be attributed to particular individuals, because that is how social and economic rewards for innovation are distributed. Indigenous societies, on the other hand, traditionally used concepts of collective intentionality, with economic systems that match such broader distribution. And indeed gambling in this context was often not for

the purpose of personal gain of the winner, but played for the communal good in a healing ceremony.

D. Native American Divination

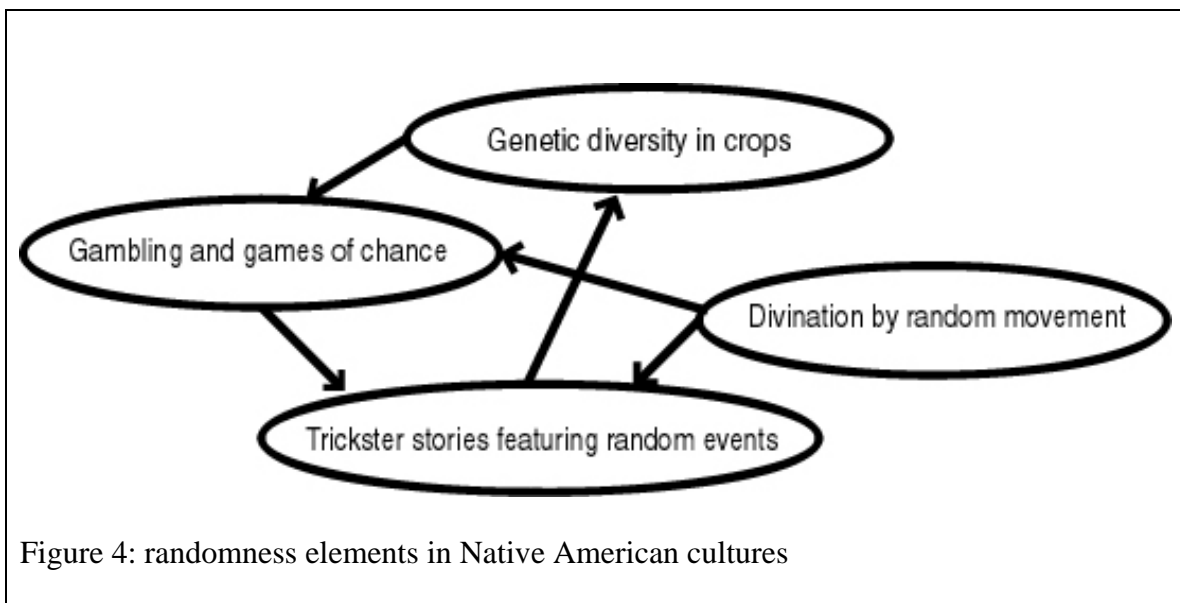
Many of the divination practices of indigenous North American cultures involved a vision quest, typically in something like a trance state. It is therefore difficult to assess in terms of a formal or mathematical description. However there were also Native American divination techniques that utilized random movement. One example was the Zuni shuttlecock. Looking a bit like European badminton shuttlecocks, with feathers attached to a weight, the Zuni version was used for both gambling purposes as well as in divination rituals. Another case of random movement in divination was the Ojibway “shaking tent,” which was a small covered framework which a medicine man would enter, followed by shaking motions of the entire structure. Trembling movements of the hand are used in Navajo divination. Olbrechts (1930) describes the use of random movements of a stone suspended by a string in Cherokee divination. Patterns in flowing water and the crackling of a fire were also used in certain Native American divination rituals.

Of course the point of these rituals is not that the movements of tents, stones, fire, and water are simply random, but rather that—given the proper conditions—information emerges out of the randomness. From stochastic variety emerges order. In a sense this is

the opposite of deterministic chaos, in which an orderly algorithm produces (seemingly) unpredictable variety.

E. Summary of randomness in Native American cultures

Figure 4 shows a summary of these cultural elements in Native American societies. My point here is that these elements are not isolated, but are rather inter-related. The trickster is sometimes involved in gambling for games of chance, gambling is also related to religion and divination; divination involves random movement, randomness is reflected in crop diversity; and so on. Again that is not to say that only randomness will be found as a Native American design theme; rather I am pointing out that there is a cluster of cultural concepts which can be inter-related through that theme.



2. Deterministic chaos as a cultural theme in African societies

A. What is deterministic chaos?

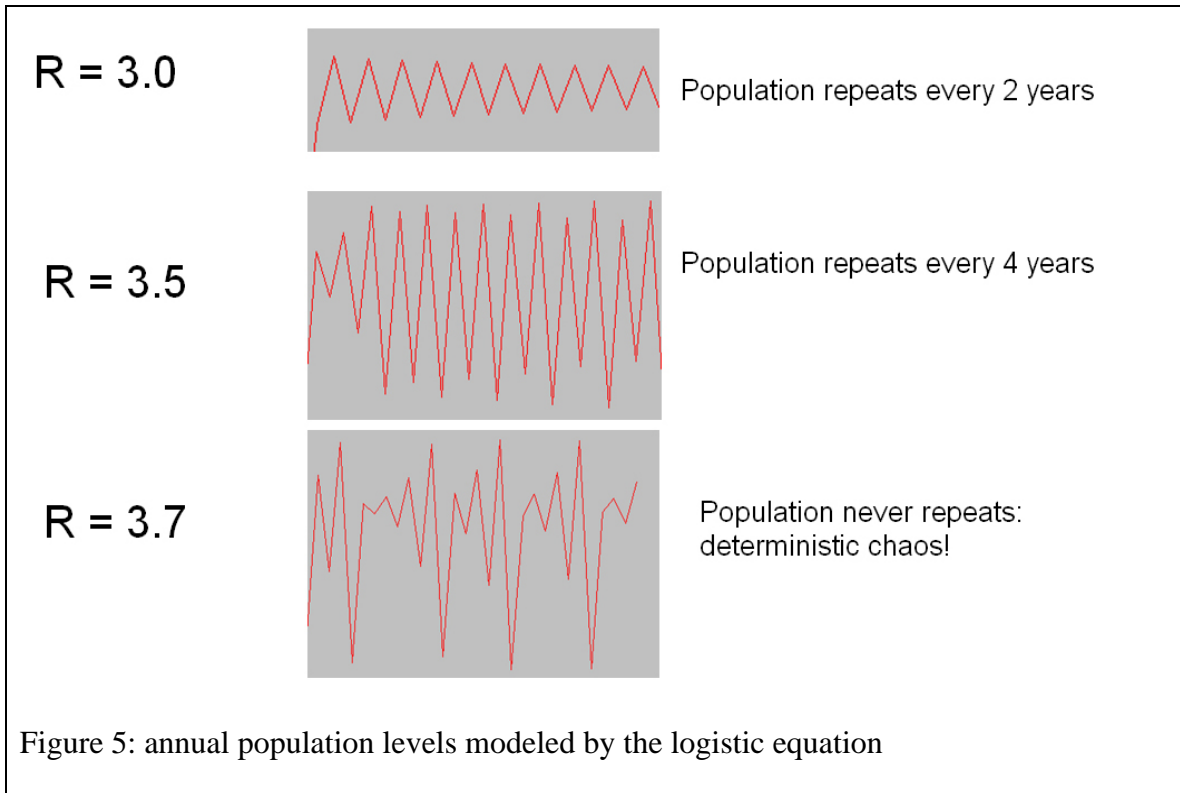
Before describing the African cultural elements utilizing deterministic chaos, I need to explain what it is. From about the time of Plato to the 19th century, mathematicians and those involved in mathematical modeling (physicists, astronomers, etc.) assumed that unpredictable behavior was due to randomness. This assumption is deeply ingrained in Western culture, and relates to a host of European cultural concepts around the issues of free will, religion, etc.

What do we mean by the words “random” and “determined”? If I flip a coin its outcome (heads or tails) is said to be the result of “chance,” but of course we know that it was actually determined by the force of the thumb flicking upward, the friction of skin and thumbnail, perhaps some stray current of air, etc. In other words if you could measure every force of every particle impinging on the coin during the flipping process, you could in fact predict whether it would be heads or tails. Mathematician Laplace expanded this concept: if you could know the position and force of every particle in the universe at one moment, and possessed the required calculating power, you could then predict everything that will ever happen, even the words that I have yet to write in this essay. After all, my brain cells are also composed of particles acted upon by physical forces. But this Laplacian determinism is disturbing to a culture with religious and political foundations

in the concept of individual free will, so we tend to gloss over it by referring to randomness or chance.² With the exception of quantum events (which we do not encounter in our daily life unless we are physicists) all the events which we describe as “random” are actually pre-determined, but generally with causes so subtle or hard to keep track of (like millions of air molecules) that we ignore their presence. It was not only the Azande who followed their cultural path in refusing to believe in the lack of cause, but Evans-Pritchard who followed his cultural path in refusing to believe in determinism.

Given this cultural emphasis on unpredictability as randomness, it is no surprise that it took mathematicians a very long time to unearth deterministic chaos (see Gleick 1986 for a popular introduction to that history). A classic example, and one that is easy to understand, can be seen in the “logistic equation”. Consider a population of rabbits, numbered for each year: P_1, P_2, P_3 , etc. If the population doubled each year—pure positive feedback—we could say “next year’s population equals this year’s population times two”: $P_{n+1} = 2 * P_n$. For a general rate of reproduction R we have $P_{n+1} = R * P_n$. But we know that there has to be negative feedback as well – death or migration. So we will think of P as something like a percentage of the maximum of 1,000 rabbits (for example $P = .5$ means 500 rabbits). That lets us make a negative feedback factor with $1 - P_n$ (the higher P_n , the lower the value of $1 - P$). Putting it all together we have the logistic equation: $P_{n+1} = R * P_n (1 - P_n)$.

Figure 5 shows what happens as we raise the value of R in the logistic equation. At first

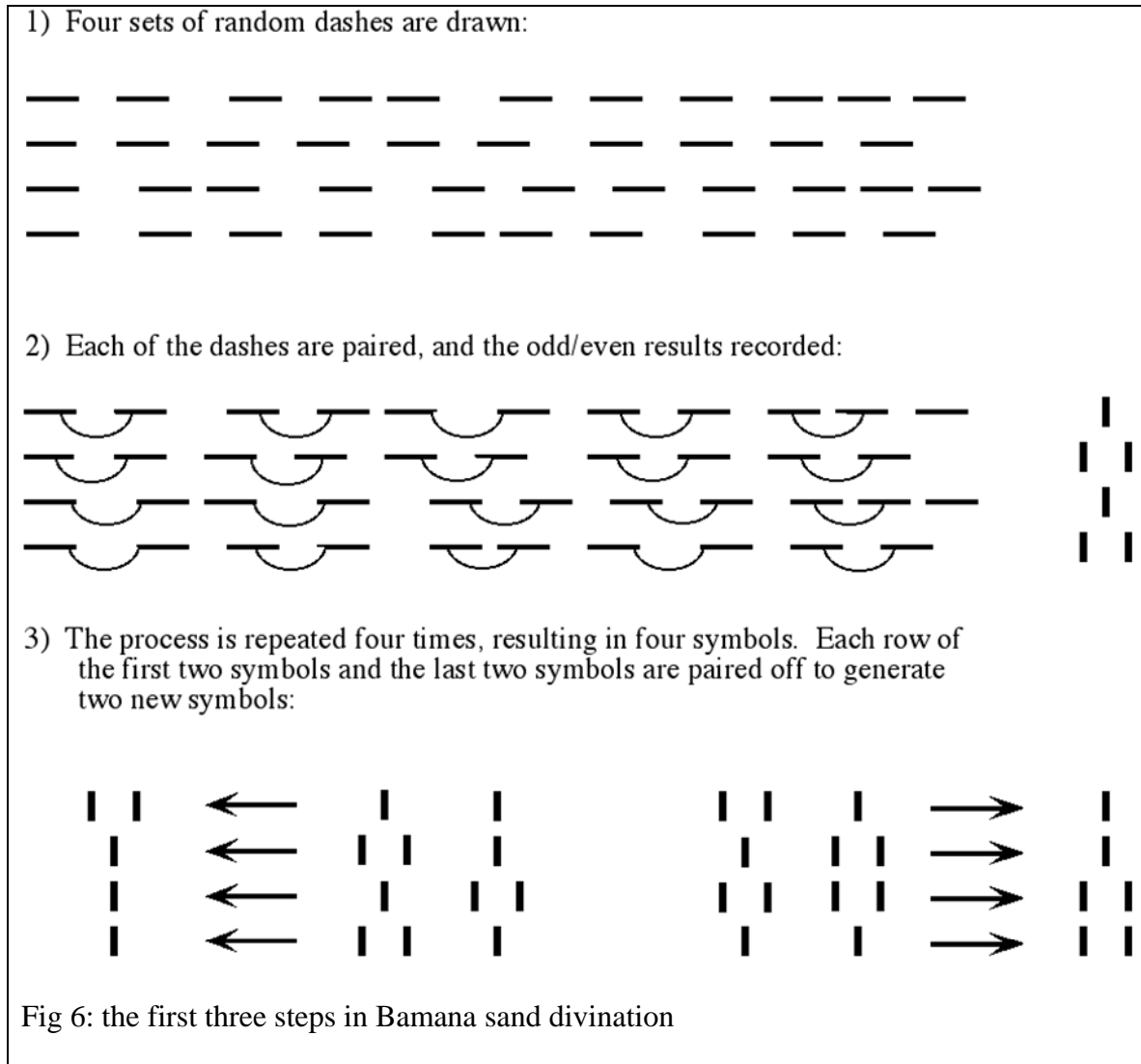


the population simply repeats every two years. Note that it takes a few years for it to settle down into a repeating pattern; this is called “transient chaos.” At $R = 3.5$ the population repeats every four years. Raising it slightly gives an eight year cycle, then 16, 32, 64, and so on. Very long cycles are referred to as a “pseudo-random number generator,” which is how your computer creates “random” values for games etc. What prevents the computer from giving you the same “random” number each time you play? Typically it uses the current date and time to create a new “seed” value so that the calculation starts differently each time. African geomancy works the same way, creating different seed values by stochastic generation (produced by random dashes in the sand or throws of counters), and then proceeding deterministically to produce the needed diversity of symbols. True deterministic chaos (which starts at about $R = 3.56$ in the above equation) gives you a cycle of infinite length, and while that is of course not

required by divination, there are many striking parallels—for example in the combination of negative and positive feedback in African religious systems, in their use of recursion in cosmologies of infinite variation, etc. I have outlined these analogous structures extensively in Eglash (1999). Here I will only give a brief description of pseudorandom number generation in divination and games, and recursion in trickster stories and fecundity concepts, for the purposes of contrast to the role that random (i.e. stochastic) variation plays in the same cultural categories in Native American societies.

B. Pseudorandom number generation in African divination.

Perhaps the best example of pseudorandom number generation in African conceptual systems is that of “geomantic” divination. It appears in many locations in Africa; here I will describe its symbol generation as I learned it from Bamana diviners in Senegal (Eglash 1997). Figure 6 shows the first two steps. The divination begins with four



horizontal dashed lines, drawn rapidly, so that there is some random variation in the number of dashes in each. The dashes are then connected in pairs, such that each of the four lines are left with either one single dash (in the case of an odd number) or no dashes (all pairs, the case of an even number). The narrative symbol is then constructed as a column of four vertical marks, with double vertical lines representing an even number of dashes and single lines representing an odd number of dashes.

The first four divination symbols are generated in this stochastic manner, but the next 12 are generated by an iterative loop in which the output of the operation is used as the input for the next stage (figure 7). In this case the operation is addition modulo 2 ("mod 2" for

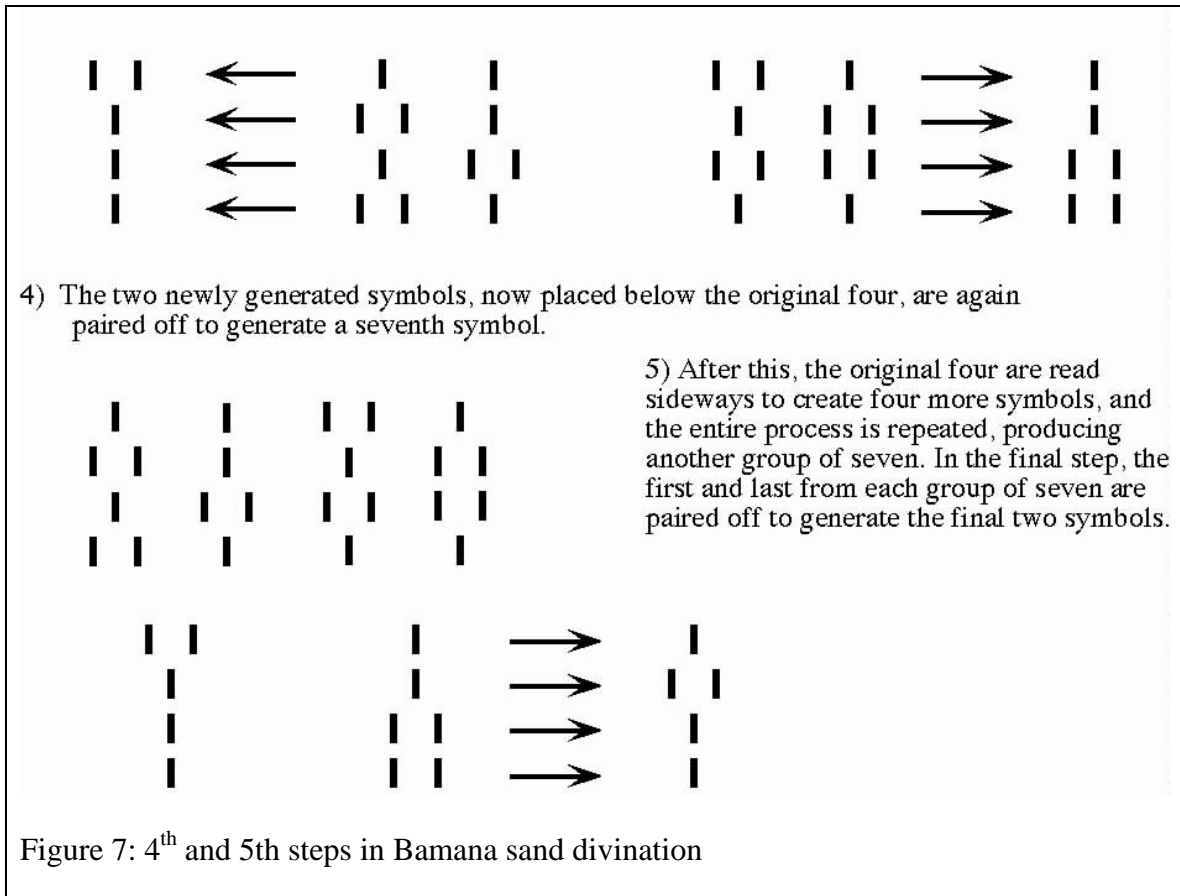


Figure 7: 4th and 5th steps in Bamana sand divination

short), which simply gives the remainder after division by two. This is the same even/odd distinction used in the parity bit operation which checks for errors on contemporary computer systems. Rather than interpret each position in the column as having some meaning (as would the Western binary number 1011, which means one 1, one 2, zero 4s, and one 8), the diviners reapply mod 2 to each row of the first two symbols, and each row of the last two symbols. The results are then assembled into two new symbols, and mod 2 applied again to generate a third symbol. Another four symbols are created by reading

the rows of the original four as columns, and mod 2 again recursively applied to generate another three symbols. The last two symbols are also generated by mod 2 recursion using the two bottom symbols to create a 15th, and using that last symbol with the first symbol to create a 16th (bringing the total depth of recursion to five iterations). Thus a stochastically generated “seed” of four symbols is used for the iterative production of 12 more symbols through a deterministic algorithm.

C. Pseudorandom number generation in African board games

Another excellent case for pseudorandom number generation in African culture is in the game variously called "ayo," "bao," "giuthi," "lela," "mancala," "omweso," "owari," "tei," and "songo" (among many other names). Boards cut into stones, some of extreme antiquity, have been found from Zimbabwe to Ethiopia (see Zaslavsky 1973 figure 11-6). The game is played by scooping pebble or seed counters from one cup, and sequentially placing one each in the cups that follow. The goal is to have the last counter land in a cup with only one or two counters already in it, which allows the player to capture those counters.

The pseudorandom aspects of the game become obvious once you begin to play: although the rules are very simple, it is difficult to foresee outcomes because a large number of seeds will go far around the board, sometimes even overlapping its point of origin. The higher the counter/cup ratio, the more pronounced this pseudorandom effect will be. Add the variation caused by different possible moves from your opponent, and the “depth” of

your decision tree (as it is called in chess) is strongly constrained by the pseudorandom effect. Here, as in divination, one can vividly see how a sense for deterministic chaos can be cultivated in traditional African epistemology.

D. Chaos from recursion in African trickster stories

In European history, recursion begins with the story of Epimenides of Crete, the “liar’s paradox.” Similar utilizations of narrative self-reference to create uncertainty can be found in certain African trickster stories. For example, in an Ashanti story of Ananse (who became “Aunt Nancy” in African-American folk lore), a man named “Hates-to-be-contradicted” is tricked into contradicting himself. Pelton (1980, p. 51) notes that the application of such self-referential paradox is a theme in many Ananse stories: “Thus Ananse rejects truth in favor of lying, but only for the sake of speech; temperance in favor of gluttony for the sake of eating; chastity in favor of lasciviousness for the sake of sex...” The following tale carries the sense of self-referential paradox quite well:

One of the most common of all stories in Africa describes the encounter of a man and a human skull in the bush. Among the Nupe of Nigeria, for instance, they tell of the hunter who trips over a skull while in pursuit of game and exclaims in wonderment, "What is this? How did it get here?" "Talking brought me here" the skull replies. Naturally the hunter is amazed and quickly runs back to his village, exclaiming about what he has found. Eventually the king hears about this wonder and demands that the hunter take him to see it. They return to the place in the bush where the skull is sitting, and the hunter points it out to his king, who naturally wants to hear the skull's message. The hunter repeats the question: "How did you get here?" but the skull says nothing. The king, angry now, accuses the hunter of deception, and orders his head cut off on the spot. When the royal party departs, the skull speaks out, asking the

hunter "What is this? How did you get here?" The head replies "Talking brought me here!" (Abrahams 1983 pp. 1).

Pelton (1980:230) contrasts the singular random events of the Native American trickster myths with “the less episodic, more narrative myths of Legba and Ogo-Yuruga [in Africa].” I would only add that the structure of these narratives is, in some sense, circular; that their disorder comes not from stochastic randomness, but recursion’s deterministic chaos.

E. Fertility and fecundity as positive feedback loops in African cultures

All cultures are concerned with fertility at some level, because they must reproduce, but the ways in which they express such concepts are quite varied. African cultures are remarkable in the ways that they use recursion for such expressions. Figure 8 shows a

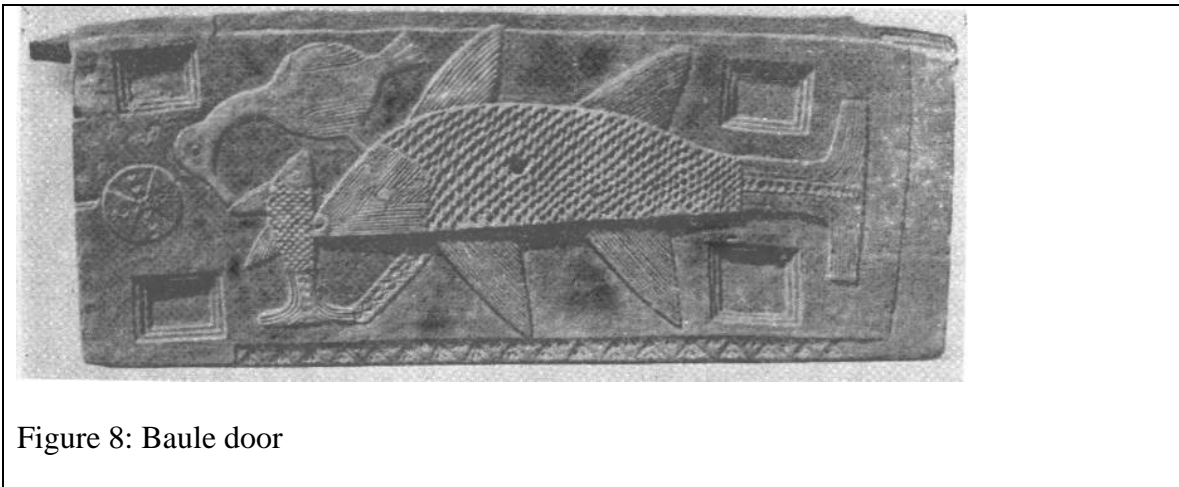


Figure 8: Baule door

Baule door in which fecundity is envisioned as a positive feedback loop; the productive “cycle of life.” Often fecundity is envisioned as a cascade of diminishing forms, as in the case of the Chi Wara headdress of Mali, or the sculpture of figure 9, also from Mali.

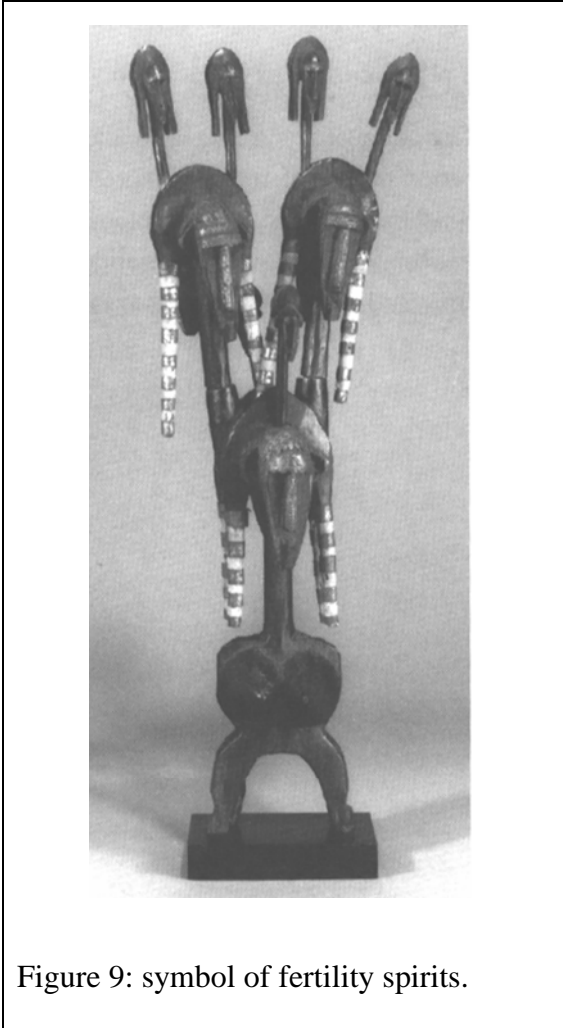


Figure 9: symbol of fertility spirits.

The African Fractals text (Eglash 1999) shows how such self-similar forms can be seen in many African designs—arts, architecture, textiles, etc. – and how their cosmological symbolism represents a deterministic unfolding of reproductive diversity and fecundity.

F. Summary of deterministic chaos concepts in African cultures

Figure 10 shows the cluster of concepts sharing deterministic chaos themes in African cultures. Again, these are not meant to imply some singular “essence” – African cultures

are quite diverse – it is merely a “family resemblance” that emerges when putting these features together in one portrait.

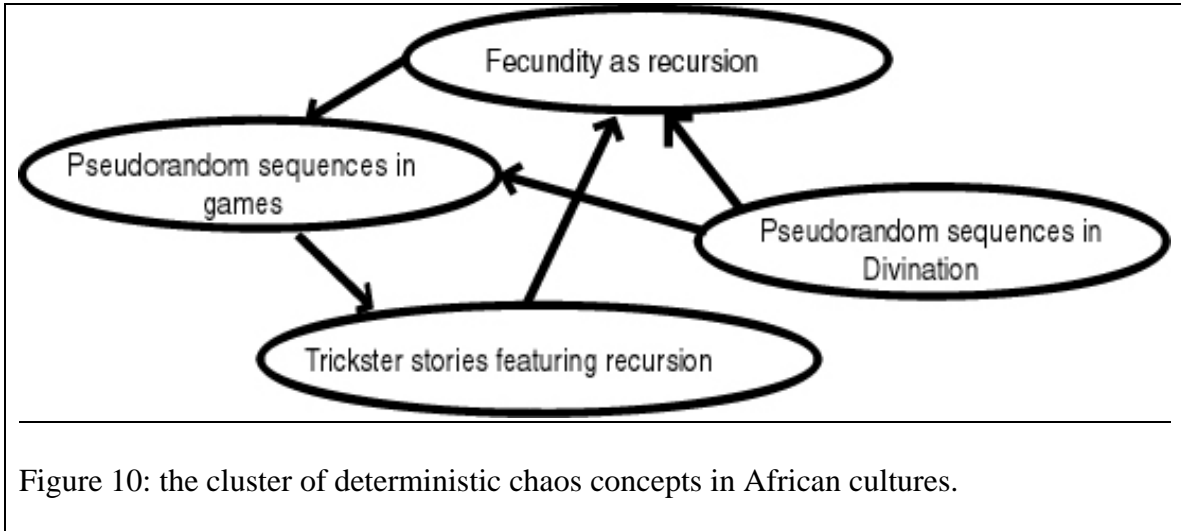


Figure 10: the cluster of deterministic chaos concepts in African cultures.

3. Conclusion

The table below summarizes the comparison I have made between African and Native

Native American	Divination by random movement	Fertility as random genetic diversity	Games as probability	Trickster unpredictable due to random behavior
African	Divination by pseudo-random calculation	Fertility as recursive fecundity	Games as pseudo-random calculation	Trickster unpredictable due to recursive behavior

American divination with respect to three other cultural categories. Again I want to caution that these are only gross generalizations – not all African or Native American cultures will have these characteristics in these particular categories. Nonetheless, I think it is important to point out that one can find a specific “flavor” to these epistemologies, particularly when considering them in terms of mathematical models or analogies.

It is particularly salient to our thinking on the evolution of culture. There must have been a co-evolutionary process in which these practices leant each other mutual support. Just as biological organisms co-evolve in ways that create a thriving ecosystem, so these cultural memes must have co-evolved in such a way that they found some mutual fit to each other.

It is also salient to our thinking about the future of these cultures, in which the survival of traditions depends—as it always has—on their adaptability and hybridity. Our work with Native American and African American children in the US has shown that their use of computer simulations of traditional cultures can be used to improve their performance in mathematics and their interest in technological careers (see <http://www.rpi.edu/~eglash/csdt.html>). Thus the application of mathematical models of divination and other practices not only shed light on the past evolution, but also offer contributions to the future in the areas of education, design, and other developments.

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¹ Four-fold symmetry is a strong geometric theme in much of Native American design; see Eglash 1999, also discussion in the cultural background section of the Virtual Bead Loom at <http://www.rpi.edu/~eglash/csdt.html>.

² Interestingly this cultural pre-occupation with free will paid off in the case of the German adoption of quantum physics. Forman (1971) shows that German physicists felt the non-causal nature of quantum events was a good fit to their rejection of socialism and its idea of social laws and pre-determined history.