

Anthro



Notes

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WHAT'S NEW IN EARLY HUMAN EVOLUTION 5 TO 1 MILLION YEARS AGO?

by Alison S. Brooks

Where do we come from? What did our earliest ancestors look like and how did they behave? In the last ten years, a flood of evidence, accumulating at an increasing rate, suggests new answers to these old questions.

Until recently, the hallmarks of "humanness" were thought to have emerged early in human evolution: full bipedalism by 4 million years ago (mya), and, by 2 mya, tools, nuclear families, division of labor by sex, hunting, long periods of childhood and adolescent dependency, and maybe even primitive language. In addition, as recently as five years ago, the family tree itself seemed rather simple and straightforward; the most common model was a tree with only 7 or perhaps 8 species in all, and only one "side branch".

Most of the time, the hominid 'niche' was filled by only one species, except between ca. 2.6 and 1.3 mya, when related species occupied the "side branch". First there was "Lucy" (*Australopithecus afarensis*), from about 3.6 to 2.9 mya. Then, there were more "evolved" australopithecines who came in two varieties: the "gracile" type (*Australopithecus africanus*) and the "robust" type with huge teeth and a bony crest on top of the skull (*Australopithecus robustus*, *A. boisei*, and *A. aethiopicus*). The former group was thought to have evolved into an early form of our own species, *Homo*, while the latter "side branch" became more and more specialized, lived alongside early *Homo* for a while (for perhaps as much as a million years) and then died out. Early *Homo*, in turn, went

through a direct progression from *H. habilis* to *H. erectus*, to *H. sapiens*, marked by increasing brain size and decreasing tooth size. Until about 1 mya, Africa, specifically eastern and southern Africa, was the only home of our ancestors, or so it was thought.

In the last five years, new finds, new dates, and new analyses have turned this simple tree into a complex bush, full of unseen connections, dead ends and mysteries. In addition, the bipedalism, bigger brains, omnivorous diets, tool-making, long period of childhood and learning, indeed the very "humanness" of early humans, have been challenged. The result has been a dramatic upheaval in our conceptions of our past. While the African roots of the family tree have remained firmly fixed, the timing and number of migrations out of that continent have been matters of considerable debate. In addition to the "where," "what," and "when" of human evolution, the "why" has also been challenged. Was it really so dry in Africa 4 mya that our ancestors had to leave the trees for the savanna? Did larger brains evolve so we could make tools?

This review of recent finds will cover five topics:

- the "oldest old" hominids;
- later stages of australopithecine evolution (news from South Africa);
- diversity in the early stages of *Homo*;
- when and why did big brains, tools and long childhoods evolve; and
- when did hominids expand out of Africa (and where did they go).

The Oldest Hominids

New finds from two regions have greatly expanded our knowledge of human evolution "B.L." (before Lucy). The first finds, announced in the fall of 1994, come from the Middle Awash region of Ethiopia, just south of Hadar where Lucy herself was found. Here, Tim White, Berhane Asfaw, and an international team of experts found the scattered and highly fragmentary remains of 16 small creatures with large molar teeth, slightly reduced canines, and a positioning of the skull on the vertebral column (backbone) suggesting upright posture. These features suggested human ancestry and an initial placement in the genus Australopithecus. Enough differences exist, however, for these fossils to be placed in a new species, A. ramidus (or "root" in Afar, the local language). For example, the enamel on the canines and molars is relatively thin, the canines relatively large for hominids, and the molars--especially the lower first deciduous or 'baby' molar--smaller than those of other Australopithecus and more elongated than square in shape. The skull opening for the ear was small as in apes rather than large as in Homo and Australopithecus.

The leader of the geological team, Giday WoldeGabriel, argues that the fossils are close to 4.4 mya, as far back in time from the actual Lucy find (3.18 mya) as Lucy herself was from the original Homo habilis at Olduvai Gorge (1.9 mya). While the teeth relate ramidus clearly to humans, the limb bones remain to be described. In recognition of the dental differences, White et al. recently suggested that the fossils also be placed in a new genus: Ardipithecus ramidus rather than Australopithecus. White has continued to work in the Middle Awash in 1994, 1995 and 1996, and has announced the recovery of at least one and perhaps several partial skeletons of different individuals.

One of the most interesting features of the ramidus find is the apparent **absence** of a savanna environment, at least in the immediate vicinity. The animal bones and plant remains reflect a forest with colobus monkeys, kudus, bats, a primitive bear, and a number of small mammals but relatively few large

savanna mammals such as giraffes, hippos, elephants, rhinos, or primitive horses.

In 1995, palaeontologist Meave Leakey and colleagues also announced a new species from ca. 4.1 mya, this one from several localities around Lake Turkana. Called Australopithecus anamensis (after 'anam' or 'lake' in the Turkana language), it was differentiated from afarensis because the lower canines were larger, the lower front premolars more asymmetrical, the molars more sloping towards their crowns, the chin region a different shape, and the earhole small as in ramidus. On the other hand, it was distinguished from ramidus by the thicker tooth enamel, larger molars and squarer molar shape.

From the asymmetry and angle of the upper part of the shin bone in the region of the knee, however, this form was clearly bipedal. Bipedal knees are quite distinctive because they are shaped so as to allow you to lock ("hyperextend") your knees "straight" while standing and to balance easily over one leg while stepping out with the other. (It was just such a knee joint that led to the finding of Lucy in 1974.) The environment of A. anamensis was less densely forested than that of ramidus, closer to the open savanna envisioned in the earlier scenarios.



NEW STUDIES OF LUCY'S
ANATOMY SUGGEST SHE
WAS ACTUALLY A "HE"

Which of these two led to Australopithecus afarensis and thence to Homo habilis? This may be a moot question, as Australopithecus afarensis and Homo habilis themselves are challenged as single

species stages on the road to modern humans. Is there more than one variant of Lucy, like the multiple species of monkeys and of chimpanzees that co-exist in Africa today? A recent find of a much larger hominid (ca. 24-25% larger than Lucy) at Hadar was interpreted by Kimbel, Johanson and Rak as a male afarensis, but could Lucy's son or brother really have been so different? Or are there two different species of Australopithecus at this time as well? A recent argument by Richmond and Jungers for multiple hominid species in the time range of Lucy suggests that new studies of Lucy's pelvic anatomy indicate that she was actually a "he". Two males of very different sizes would certainly argue for at least two species.

Kimbel et al., however, contend that Lucy's pelvic shape is due to her posture while walking and not to an incorrect determination of her sex. Differences in limb anatomy could mean not different species but simply that the heavier males spent more time on the ground while females spent more time in the trees. Furthermore, they argue, not only do all the fossils attributed to afarensis belong in a single species, but the species lasted unchanged for almost a million years. This conclusion is based on comparisons between a new almost complete skull from Hadar at 3.0 mya and a new frontal (forehead and brow regions) from Belohdelie in the Middle Awash region just south of Hadar, dated to 3.9 mya.

If early australopithecines were not restricted to savanna environments, were they confined to east Africa? A recent paper describes a new fossil from Bahr el Ghazal in the west African country of Chad, more than 1500 miles west of the east African rift valley sites. The fossil mandible is comparable to afarensis but with thinner tooth enamel and other distinctive traits so it could represent another new species. It is dated to around 3.0 to 3.4 mya on the basis of the primitive elephants, horses, pigs, hippos and rhinos found with it. These are interpreted as indicating a mixed forest and woodland with some grassy areas, rather than an open savanna. Further exploration will probably expand both the range of the ancestral hominids and their variety.



News from South Africa

The first australopithecus find in 1924 consisted of a child's face, brain cast, and mandible from the South African site of Taung (Australopithecus africanus). The first recognition of different robust (r) and gracile (g) australopithecine species was also based on South African sites: Sterkfontein (g) and Kromdraai (r) in the 1930s, Makapan (g) and Swartkrans (r) in the 1940s. In recent years, although work continued at these four sites, the main action appeared to have shifted to east Africa, where periodic volcanic eruptions and rift valley sedimentation allowed palaeoanthropologists to find and date actual surfaces where australopithecines had lived. Dates and ancient landscapes were much harder to reconstruct in the cave sites of South Africa. Also, for much of the 1980s and early 1990s, South Africa was isolated from the rest of the scientific community for political reasons.

This year, South Africa is suddenly in the early human news again with new finds that shift the picture of human evolution. There are two new fossil sites: Gladysvale and another site as yet unpublished, each with a new series of human remains. Sterkfontein, the first site to yield an adult australopithecine of the gracile variety ("Mrs. Ples"),

now contains evidence that more robust forms were there as well at the same time. And at least some of these human ancestors may have been able to hold onto things (like tree branches) with their feet. Newly published foot bones from one of the oldest levels (member 2 ="level") at Sterkfontein, comparable in age to Lucy, show a big toe that stuck out at a slight angle to the other toes. Were there any trees to hold onto? New paleobotanical studies at Sterkfontein from the main australopithecine level (member 4) recovered fossilized vines or lianas (the kind that Tarzan swings on in the old movies) that today occur only well inside the tropical forest far to the north. No open savannas here either!

In addition, the younger horizon at Sterkfontein (member 5) has now yielded Oldowan tools dated to about 2.0 million years, slightly older than Olduvai and more "primitive" in their manufacture. Sterkfontein's archaeologist, Kathy Kuman, has suggested most of them were made by smashing quartz cobbles on a hard surface and picking out the good flakes. Who made these tools? Sterkfontein yielded another hominid, younger than the tools and provisionally classified as Homo, but Ferguson has suggested that it may be too robust for Homo and might possibly be reclassified with Australopithecus.

Was Mrs. Ples, who comes from the underlying horizon dating to 2.5-3.0 mya (or someone like her but slightly later) the toolmaker? Since gracile australopithecines were supposed to have been ancestral to Homo, while the robust forms were on a side branch, many scenarios had the late gracile forms experimenting with tools, despite the absence of any evidence for tools in gracile sites. (Tools do occur with later robust forms!) Like Lucy, Mrs. Ples may soon undergo a sex change operation and, at the very least, assume a new identity. A recent careful examination of the top of her skull suggested that something was missing. Fortunately, the piece of rock that once encased her skull had been saved. Stuck into this rock were the remnants of a small sagittal crest. Gracile females did not have this feature. Either "Mrs. Ples" was really "Mr. Ples" or else she is one of the earlier members of the South African robust line.

At this point, the taxonomy becomes really confusing. If the Homo from Sterkfontein is really Australopithecus, and if the type fossil of an adult Australopithecus africanus is really a robust form like Australopithecus (or Paranthropus) robustus, then who is Australopithecus africanus anyway? Since the original A. africanus was a child's skull and braincase, we really have no way of knowing exactly what it would have looked like when it grew up. There will certainly be many years of arguments before these and other queries surrounding the fossils we now have are resolved, let alone the questions raised by new finds.

One postscript to the Taung story involves a fascinating bit of detective work. Most South African sites consist of remains of the lairs of predators who ate australopithecines for dinner, as suggested by the many carnivore tooth marks on hominid skulls and bones. Taung was always different from the others. Despite the mining of what was probably the entire cave, only the three pieces of the Taung "baby" were recovered. No larger or more complete fossils of anything ever turned up. The damage on the Taung skull was also different -- sharp triangular nicks on the edges of the bone, and a distinctive dent in the top of the skull where the thin cranial bone was pushed into the brain. What could have made this damage? Ron Clarke and Lee Berger studied damage from many different types of carnivores and concluded that the only possible agent of destruction was a large eagle, whose talons poked a hole in the skull, and whose curved beak took distinctive bites out of the bone. This would explain why no australopithecine (or other large mammal) adults ever turned up there -- they were too big for an eagle to carry.



Early Homo: How Many Species?

The early evolution of our own species was also once thought to be a simple affair. Tool making, an enlarged brain and smaller teeth marked the emergence of Homo habilis at 1.9 mya. These features were functionally linked together by reasoning that teeth could not be smaller on a larger creature unless some "food-processing" was done outside the mouth, i.e. with tools. By 1.5 mya, even larger brains and modern body size marked the appearance of Homo erectus, who subsequently spread out of Africa. Finally, by about 500,000 years ago, early forms referred to as "archaic" Homo sapiens appeared in both Europe and Africa.

The number of species suggested for our own genus has also increased recently, and the relations between them have grown more complicated. What used to be called Homo habilis is divided into at least two, and possibly three, species, while the early Homo erectus fossils from Africa are sometimes put in their own species, Homo ergaster. In the later stages of Homo, once all grouped in the species sapiens, some authors place the early "archaics" in a separate species, "Homo heidelbergensis," and may further delineate the later Neanderthals as "Homo neanderthalensis." The species designation "sapiens" is reserved by these authors for modern humans only. Were all of these groups separate species that could not interbreed and had different adaptations? Did our previous "single species" view of the evolution of Homo obscure what was really happening?

Within a few years of finding the original Homo habilis at Olduvai, a very different early form had turned up to the north at east Turkana. This form, dated to the same time, had a larger brain but retained rather large teeth. The Olduvai fossils had small teeth, but brain sizes only slightly bigger than those of australopithecines. Bernard Wood has argued for the name "Homo rudolfensis" (after the old name for Lake Turkana) for the larger-brained Turkana form, and retains the name habilis for the smaller form, whose skeleton, recovered in 1985, suggests Lucy-like proportions of arms and legs. How did these two differ in their behavior? The record is not yet complete enough to tell. Both used

simple stone tools and occur in the same kinds of environments, usually more open and grassy than those prevailing before 2.5 mya. The difference is not due to geographical separation; a very early example of rudolfensis dating to over 2.0 mya was reported in 1993 from the Malawi sector of the east African rift, well to the south of Olduvai. Which one led to modern humans? This, too, is unclear, and may never be determinable if new early species continue to be found. Perhaps more detailed environmental and behavioral studies now underway will reveal some answers.

Why bigger brains?

Theories about the origin of the large human brain have focussed on many aspects of behavior that were supposed to have driven this change. An early view pointed to hunting. When it was shown that early humans were more likely to have been scavengers, the focus changed to tool-making. Recent dates of 2.5 mya for the earliest tools, at the Gona sites near Hadar in Ethiopia, predate the earliest evidence for an enlarged brain, and suggest that tool-making came first, brains may only have followed hundred of thousands of years later. (New early fossils of Homo from Malawi, as well as from Ethiopia, may change this perspective as well.) Another theory is that brains became larger to take advantage of a longer period of learning and childhood development. New ways of studying growth rates in early humans, however, have shown that australopithecines were more like apes than like modern humans in their growth patterns, and that even Homo erectus was not yet fully human in this respect.

Scholars have tended to assume that the reason that brains did not get larger earlier is that they were not needed. A new theory, the "expensive tissue hypothesis" has argued instead that brains could not become larger earlier, because they used up too much of the body's energy -- ounce for ounce, the mammalian brain uses nine times as much energy as the rest of the body, on average. Leslie Aiello and Phillip Wheeler point out that five major organs or organ systems use up 60-70% of the body's energy at rest, although they account for only 7% of the body's total mass. These "expensive" organs are the

gut, the heart, the liver, the kidney and the brain. (Lungs are also quite "expensive.") Unless the animal eats a lot more high calorie foods (very unlikely in the case of humans, to judge from the teeth) *or* one of these organs gets smaller, there is no energy budget left to feed a larger brain.

What got smaller around 2 mya that allowed the brain size to finally increase? The heart, liver and kidney are scaled to body size (mass); they cannot get smaller unless you do. The only remaining possibility is the gut, which could become smaller if foods were either higher quality or partially "digested" outside the body by tools. Lucy's rib cage suggests that her gut was enormous, and that her body proportions were more similar to those of a gorilla than to a modern human. No wasp-waists or hourglass figures among the australopithecines -- indeed no waists at all! On the other hand, the oldest relatively complete skeleton of early Homo, the 'boy' from Lake Turkana (see *Anthro. Notes*, vol. 9, no. 3, fall 1987, pp. 11-15) while much larger than Lucy, has both a larger brain **and** a delicate waist and flattened rib-cage like ours.

But if changing food patterns made big brains possible, what made them desirable? A new book by Rick Potts of the Smithsonian's Human Origins Program argues that the major adaptation of early Homo was the ability to deal with rapidly changing climates and diverse environments, what he calls "variability selection." As climate swings became more severe, brain size and body size increased, and learning rather than instinctive behavior was at a premium. The major shift towards greatly expanded brains relative to body size took place not in the early stages of human evolution but around 500,000 years ago, with the onset of the dramatic climate changes associated with major ice ages and associated changes in the tropics.

Out of Africa: When and to Where?

When did humans first expand out of Africa, and where did they go? Only a few years ago, the general patterning seemed to indicate that the exodus was just before 1 mya, that the human type involved was Homo erectus and that the destination was Asia, not Europe. The earliest well-dated sites

with definitive traces of human activity in Europe all appeared to cluster in the Middle Pleistocene after about 730,000 or even 500,000 years ago. New dates for both Asia and Europe as well as new finds suggest that this scenario, like the others mentioned in this article, may be far too simplistic.

The most widely accepted early dates in Asia are for 'Ubeidiya, a well-known site in Israel where Oldowan artifacts appear to go back to ca. 1.4 mya based on faunal comparisons with Africa. New chronometric dates for the eastern part of the continent have been even more surprising. Carl Swisher and Garniss Curtis of the Berkeley Geochronology Center have published several dates older than 1.0 mya for the Modjokerto child, an early Homo erectus find from Java. These cluster around 1.8 mya. Some who disagree with these dates have argued that while there is indeed a volcanic ash near the site of the find that is of this age, it is far from clear how that relates to the age of the find, which was made by a local farmer in the 1930s. Swisher and Curtis have responded that the ash that lines the skull is a close match chemically to the dated ash; others have either disputed their conclusions or pointed out that **both** the ash **and** the skull could have washed into the site together. In the latter case the skull could be much younger than the ash. The continuing accumulation of new dates for other sites in Java such as Sangiran, however, appear to confirm the presence of Homo erectus in Java between 1.4 and 1.8 mya.

An even more controversial site, Longgupo, in South China, was recently described by Huang, Ciochon and others in both *Nature* and *Natural History*. This site contains a small jaw fragment of what the authors argue is early Homo, either habilis or ergaster, the first such fossil outside Africa. The find was associated with early Asian mammals (Late Pliocene to early Pleistocene in age) including a giant ape (Gigantopithecus). Also found were two very minimally fashioned objects of stone that the authors argue are tools. The possible attribution to habilis is based on the size and forward position of the cusps of the second premolar together with its double root. Others point out that these characteristics are not unknown from Homo

ergaster or early erectus, or even some early Asian apes.

In addition, the dating of Longgupo is based on paleomagnetism, which measures the direction and strength of the earth's magnetic field in samples of earth taken from around the bones. The earth's magnetic field periodically dissolves, reorganizes and changes direction; 800,000 years ago, for example, a compass needle would have pointed south rather than north. These reversals are encoded in newly forming sediments, as the atoms align themselves with the prevailing magnetic field at the time. The ancient magnetic signal is locked in to the sediment and can be measured in the lab. Precise dating of reversals in **volcanic** sediments using the potassium argon technique has led to a sequence of ages for 'normal' (north-oriented) and 'reversed' (south-oriented) periods. In **non-volcanic** sediments, such as those at Longgupo, researchers must try to guess which 'normal' or 'reversed' interval they are looking at, based on the entire sequence. The important levels at Longgupo are 'normal', below a layer that is 'reversed' and several meters below a date of 1.02 mya, based on the decay of uranium isotopes in a sample of fossil tooth enamel and dentine. The researchers argue that the closest 'normal' period before 1.02 mya is the one at 1.78 to 1.96 mya. If the uranium series age is closer to 0.78 - 0.84 mya, which the authors admit is possible, then the earth around the 'human' bones could date to 0.9 to 1.0 mya, also a normal period, and much closer to the age of other old Chinese hominids.

What about Europe? The oldest European, and the only clear Homo erectus fossil from that continent recently turned up in the Republic of Georgia, in the Caucasus Mountains that separate Europe from the Near East. The fossil jaw, which looked very much like one from Kenya, was located above a basalt flow dating to 1.8 mya. in a normally polarized horizon. One additional problem is that the find was not in some undisturbed cave but in the wall of a medieval storage cellar in the town of Dmanisi. A recent expedition suggested that the fossil came from a series of burrows or dens, excavated by prehistoric mammals. Although the earth into which the dens were excavated is of normal polarity, the

earth that fills the dens is reversed. This means that the fossil is **younger** than 1.8 mya (when polarity was normal) but must be older than 0.78 mya (polarity has been normal from that time to the present). The most likely estimate at the moment is ca. 1.4 mya, around the same age as 'Ubeidiya.



A final European site in the news is much further into Europe than Dmanisi: the site of Atapuerca in northern Spain, where literally hundreds of human bones have been recovered from narrow fissures in the rock. Most relate to Middle Pleistocene times, but in the oldest site, the dating may suggest an age of 800-900,000 years ago. It is especially interesting that these are **not** classic examples of Homo erectus, but already suggest some specializations in the direction of Neanderthals, such as tooth row with a space behind the last tooth, deep pulp cavities in the teeth, semicircular brow ridges, and some enlargement of the middle face. How did all those human bones end up in this area? Excavation and analysis of this site are ongoing, and perhaps further publication will soon enlighten us.

Ex Africa Semper Aliquid Novi

(Ancient Greek proverb, "Always something new Out of Africa," cited by Pliny the Elder and Charles Darwin)

Just as we thought that the general picture of human evolution was becoming clear, new finds have suggested that our picture was too simplistic. The tree is more bushy, the causes more complex, and the migrations multiple and in several directions. These are very exciting times in palaeoanthropology, and we look forward with great anticipation to the next few years of research and analysis.

Readings

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New Species of early Homo: Wood (1992) *Journal of Human Evolution* 22: 351-398 **Malawi:** Schrenk et al. (1993) *Nature* 365: 833-836 (see also comment by Wood on pp. 780-790)

Expensive Tissue Hypothesis: Aiello and Wheeler (1995): *Current Anthropology* 36(2): 199-221 (with comments by 9 other scholars)

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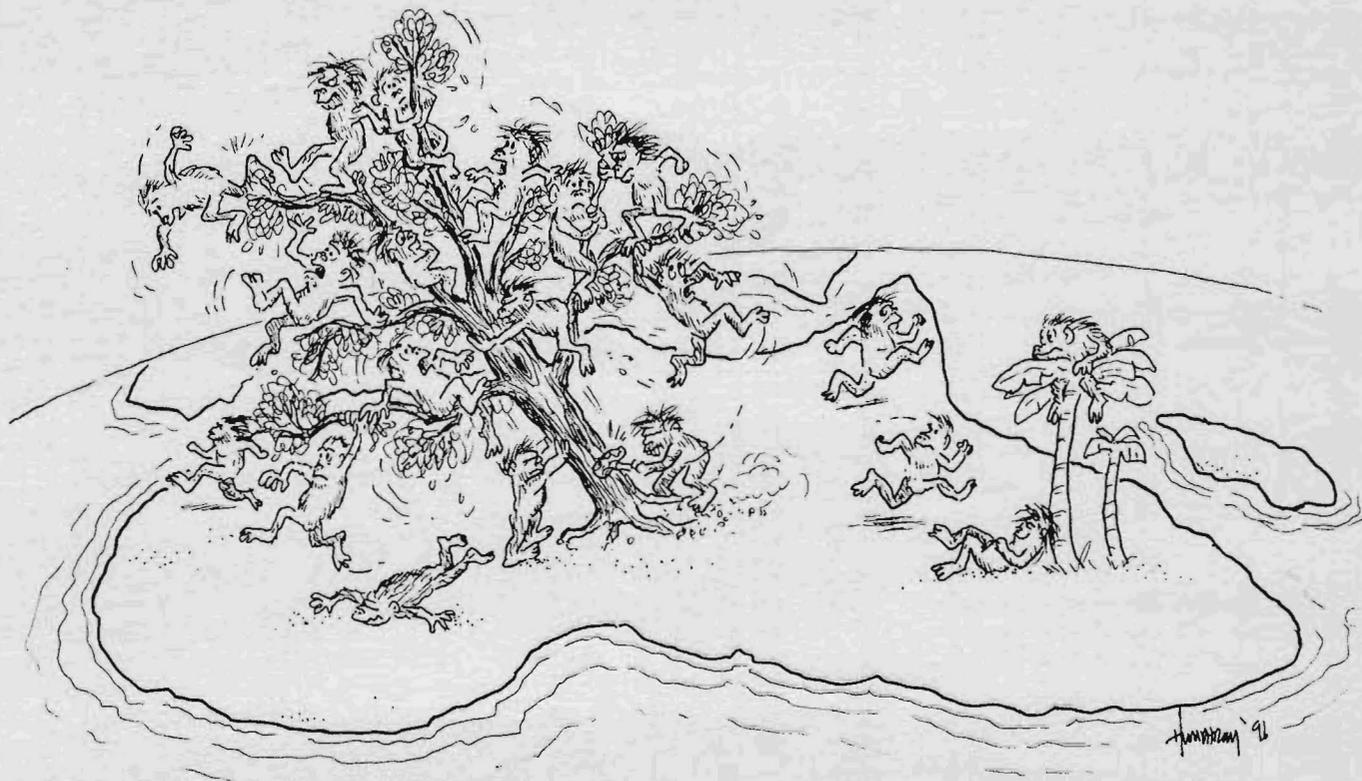
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The ERIC network (Educational Resources Information Center) has just finished updating its Anthropology InfoGuide. The InfoGuides point K-12 educators to Internet, ERIC, and traditional print information resources in specific topics of interest. This particular InfoGuide includes URL addresses for museum-based web exhibits in anthropology. To find the guide, visit <http://eric.syr.edu> and enter the Virtual Library.



SHAKING THE FAMILY TREE

TEACHER'S CORNER: BEAN BAG POPULATION GENETICS

by Jeffery W. Froehlich and Marilyn R. London

How does evolution "work"? This exercise defines basic terms and describes experimental procedures for teachers to use when explaining concepts in evolution. Students work in teams of two, and each team completes two separate experiments demonstrating 1) random genetic drift, and 2) natural selection. Since each team must complete up to ten trials for each experiment, the teacher may want to plan this activity for two class periods.

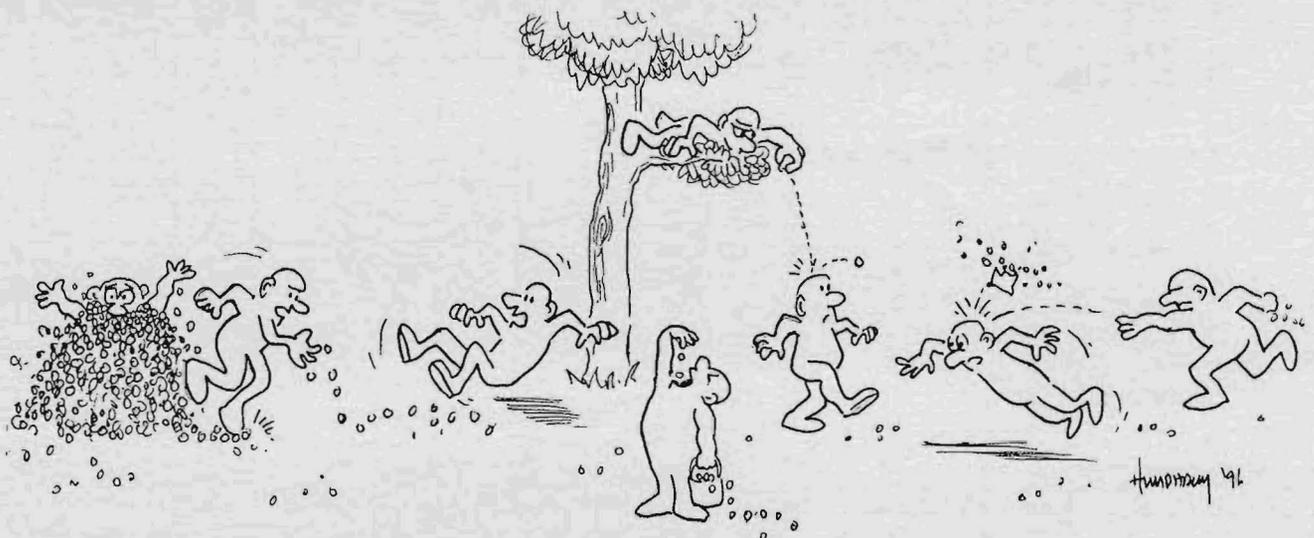
After all the experiments have been completed, the teams can regroup for a discussion of the experimental outcomes. Under the Reports section of this exercise, guidelines are offered for each group's written summary of the experiments. Teachers can focus on the following for class discussion: How do the experimental procedures differ? How does the sample size of beans affect the outcome of the experiments? How are the outcomes of the experiments similar? How are they different? How do the two evolutionary forces demonstrated--random genetic drift and natural selection--change populations differently?

It is difficult to predict the exact outcomes of these experiments, just as it is difficult to predict evolutionary changes. However, the teams can compare their different results, and discuss how the

changes in their populations occurred (gradually or suddenly) through the steps of the experiments.

These different results, and the variation in how they are achieved, simulate evolutionary change in the natural world. By the end of the discussion, students should be able to articulate how seemingly minor evolutionary changes can have enormous impact on small populations.

Evolution is normally studied in terms of *populations* instead of *individuals*. In the classroom, it may seem impossible to set up a laboratory procedure that will help students to understand the forces of mutation, migration, random genetic drift, and natural selection--which all act on populations. However, many of these concepts can be demonstrated in a very basic way. In this activity, beans of two different colors are used to represent two alleles of a single gene that controls a single trait, such as a gene that controls for eye color. The frequency of each color of bean may change from one generation (experimental trial) to the next. (Remember that higher organisms have two copies of each chromosome, one copy originating from each parent. Consequently, the two chromosomes may have different alleles of the same gene depending on what alleles the organism's parents had.) This is a fairly simplistic demonstration that does not take into account dominance, linkage, or other complexities of genetics, but its simplicity will give students an appreciation for how the genetic makeup of a population can be altered over time by seemingly minor forces.



Terminology

Several terms are used to explain differences in populations and how populations change over time. These terms should be used when the students write their reports at the end of the experiments.

- A **gene** is a segment of DNA that contains all of the information necessary for the expression of a protein or structural RNA.
- **Alleles** are variants of a single gene, found in the same position or locus on a chromosome; they represent the possibilities for variation in a population with respect to a particular inherited trait.
- **Locus**: refers to a location on a chromosome occupied by a gene (which may have several alleles).
- **Gene frequency** represents how often an allele occurs in a population. The number of alleles for a particular trait is divided by the total number of genes in the sample of the population you are counting. Gene frequencies are always expressed in decimals, so that if a gene (allele) is present in 50% of a population, the gene frequency is 0.5.
- **Fixation** of an allele occurs when, through evolutionary processes, the gene frequency of one allele at a locus becomes 1.0 (everyone in the population has that allele) or has disappeared from the population entirely (gene frequency = 0.0).
- **Evolution** is a change in a population's gene frequencies over time. Evolutionary forces are processes that can change gene frequencies.
- **Breeding population** describes the part of the population likely to interbreed. An entire species can be considered a breeding population because, theoretically, all members of a species can interbreed. In the real world, however, many individuals do not breed in their own group for some physiological reason (such as age), or between groups (for behavioral or geographic reasons). In population genetics, the breeding population consists only of the individuals that can potentially mate and produce viable offspring. Only breeding individuals have the potential to contribute genes to the next generation.
- **Population genetics** is the study of the behavior of genes and their alleles in populations.
- **Selection** describes a force that determines which genes are passed on to the next generation.
- **Natural selection** is the effect of the environment's interaction with each individual; it acts directly on the individual's phenotype and therefore, indirectly, on the genotype. It is directional because the environment will "favor" the survival of some individuals over other individuals; for instance, if there is a gene that allows certain individuals to store fluids better, these individuals would have an advantage during times of drought. The term "fitness" describes the relative reproductive success of different individuals in a particular environment. Those who survive to produce offspring, which then survive to reproduce, are more fit than those who do not meet both requirements. The "fittest" are those that leave the highest number of viable offspring. Natural selection acts on individuals, but individuals do not evolve.
- **Artificial selection** occurs when a conscious effort is made to change the genetic makeup of a population, as when humans choose "attractive" or economical traits in animal breeding.
- **Phenotype** is the description of visible traits that characterize an individual or members of a population. Phenotype can reflect both an individual's genetic makeup and the effects of the environment on an individual.
- **Genotype** is the hereditary makeup of an individual.
- **Mutations** are changes in the genetic material. Not all mutations are "bad"--without mutations there would not be variability (in genetic terms, alleles). Because mutations occur very infrequently, they are very slow to change gene frequencies in a population--unless it is a very small population.

•**Random genetic drift** refers to a change in gene frequencies that is completely random, i.e., there is no necessary selection for or against a particular allele. The allele simply occurs, by chance alone, more or less often in a generation than in the previous generation. This drift has no particular direction -- it can go back and forth. In order for this drifting to influence the entire population's genotype frequency, it is necessary to have a small population. It is possible for a small population to continue to drift toward or away from a particular gene frequency, in which case it can reach fixation (all or none).

•**Migration** refers to the flow of genes into or out of an isolated population through inbreeding. A small amount of **gene flow** often occurs between populations that normally do not interbreed. As with mutation and random genetic drift, migrants carrying different alleles into or out of a population have a much better chance of changing the population's gene frequencies if the population is small. Migration is a way to "un-fix" a particular allele in a population.

•**Founder effect** occurs when a small group of individuals forms a new population, which is isolated from the original population. The gene frequencies of subsequent generations may be very different from the original population simply because the small number of individuals who are founders probably do not carry all the allelic forms found in the original population.

Bean Bag Population Genetics Activity

In this activity, beans of two different colors demonstrate evolutionary forces, plus the effects of population size on these forces. Use red and white beans of similar size. In these experiments, the beans represent two different alleles for a gene controlling a single trait. To approximate the possible distribution of genes in populations, nine different "populations" of beans must be prepared. In small containers, such as shallow bowls or jars, create populations of 100 beans. In the first container there will be 10 red beans and 90 white beans (10R/90W; gene frequency of the red beans is 0.1); in the second there will be 20 red and 80 white

(20R/80W; gene frequency of the red beans is 0.2); in the third there will be 30 red and 70 white (30R/70W; 0.3); and so on until you have 90 red and 10 white beans (90R/10W; 0.9) in the last container. The containers should be carefully labeled with both the number of beans and the gene frequency, so that it is easy to determine their contents.

Students work in pairs. Each team requires two small empty containers; a pair of tweezers; a paper plate, with a few random openings large enough for some beans to drop through; a large coffee can; and two recording sheets (see below).

Procedures

Experiment 1: This experiment demonstrates **random genetic drift** in different sized populations by showing the effects of sampling a small number of genes from a population in order to form the next generation. When populations are so small that not many individuals are reproducing, the effect of random genetic drift is greater. The differences in sample size will demonstrate how change can occur more quickly when populations are small.

a) Using the tweezers, and without looking at the beans, one student draws 5 beans from the 50R/50W container, where the gene frequency of the red beans is 0.5. The 5 beans are placed in the student's empty container. Count the number of red beans in the container, thereby determining the gene frequency of this new "population," record this new gene frequency on the sheets, and return the beans to their original container. For instance, if there are 2 red beans and 3 white beans in the student's container, the gene frequency is determined by dividing 2 (the number of red "alleles") by 5 (the total number of "genes"); the gene frequency is 0.4. Find the container that has the same gene frequency as the new population (in this case, 40R/60W), and draw 5 beans from that container. Again, count the number of red beans, determine the gene frequency, record your findings, and return the beans to their container. The experiment is repeated until 10 generations (trials) are simulated, or until the gene frequency reaches **fixation** (all red or all white beans).

b) The second member of the team repeats the procedure, starting again with the 50R/50W container, and recording all of the trials.

c) The first student collects data in a similar fashion to the original experiment, but draws populations of 10 beans in each trial instead of 5. All data are recorded on the data sheet.

d) The second student repeats the procedure with populations of 10.

e) The procedure is repeated by each student, drawing populations of 20 beans in each trial.

Experiment 2: This experiment is designed to demonstrate **natural selection** by using a "screen," in this case, a paper plate with holes randomly poked through it, as a selective agent. Selection is the only directed evolutionary process, where an external or environmental factor influences the survival and reproductive success of particular genes. The "screen" in this experiment acts the same way as a change in the environment might act. Since the beans are not uniform in size, the screen (the external factor) will "select" the desirable beans. Changing the sample size (5, 10, then 20) will demonstrate how the size of the population can determine how rapidly evolution occurs. The paper plate is laid on top of the coffee can and pushed in a little to stabilize it.

a) Start again with the 50R/50W container and a population of 5. Pour beans slowly directly from the 50/50 container until the correct population (in this case, 5) falls through. If the can and screen are shaken to "help" the beans through, they must be shaken for every trial. If too many beans drop into the coffee can, the trial must be repeated.

b) Repeat as in Experiment 1, so that there are two experiments each for the population sizes of 5, 10 and 20, with each experiment running to fixation or 10 trials. Record the frequency of red beans on the table for each experiment.

Reports

Using the data collected, each team writes up a few paragraphs about each experiment. The following information should be included:

a) a description of the purpose of the experiment, and the procedures, in the students' own words;

b) a discussion on how sample size affects the outcome of each experiment;

c) a comparison of the outcomes of the two experiments (how the results of the experiments are similar, and how they are different) and;

d) an analysis of how the forces of evolution demonstrated in these experiments--random genetic drift and natural selection--affect population change differently.

Recording sheet: TRIALS

Sample Size↓	1	2	3	4	etc
5 (student 1)					
5 (student 2)					
10 (student 1)					
10 (student 2)					
20 (student 1)					
20 (student 2)					

Student names _____

Experiment _____

Make two copies of the table for each team. Record the data for each experiment on a separate table, and label the tables clearly. The data (frequencies) may also be recorded on graph paper, if desired.

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MAYAQUEST: AN INTERACTIVE LEARNING EXPEDITION

[Editor's Note: What happens when you link teachers and students in North American classrooms with a team of adventurers and archaeologists bicycling across Mexico and Central America in search of the lost Maya Civilization? For three months in 1995, and again in 1996, the MayaQuest team travelled over 2,000 miles through Guatemala, Mexico, Belize and Honduras. Through satellite phone hookup and Internet and Prodigy connections, classrooms in 42,000 U.S. schools traveled with them. This was no ordinary e-mail project but a highly orchestrated and complex undertaking that included on line-chats (though not with team members themselves), user groups exchanging over 77 lesson plans in English and Spanish, World Wide Web pages, dialogue with on-line experts, live student-produced TV broad-casts and CNN weekly updates. *AnthroNotes* first reported on MayaQuest in the fall of 1994; what follows are the assessments of an archaeologist, computer specialist, and educator involved in the development and implementation of MayaQuest.]

The Archaeologist's Perspective

I had agreed to give a school talk on Classic Maya archaeology to an elementary school participating in MayaQuest. But I was running late, and annoyed that it was taking time away from my planning for Minnesota Archaeology Week. Arriving out of breath and several minutes late, I began to set up my slides, only vaguely aware that a lot of noisy kids were trooping into the room that was being enlarged as teachers folded back partitions.

When I turned around to face the class, I just stood there, amazed, and stared. What I experienced completely validated my decision to help develop MayaQuest; the students I was visiting clearly were participating in an exciting adventure-learning project that had captured their imagination and led them on their own personal quest. My experience that day highlighted all the positive aspects of being involved in this public education project.

The scene before me was a completely transformed environment. Behind the dividers, the room had been turned into a jungle--paper trees and vines, birds and New World monkeys hanging from the ceiling. Palenque's Temple of the Inscriptions was there, complete with Pacal's tomb behind a tiny cardboard flap. These students had not only been following the MayaQuest bicycle expedition; they had been living and breathing the ancient and modern Maya and their environment for weeks. My talk became a reinforcement of their experiential learning and discovery through MayaQuest. These one hundred kids were with me every step of the way. They had good questions, were prepared to learn, and wanted to use me to check the accuracy of their data. My visit was an integrated component of their unit on the Maya. It was an exciting moment of validation for me that the impact this experiment had had on these enthusiastic students was well worth the effort many of us had put into it.

This project teaches us that we must look for partnerships and be open to opportunities. We have to guard against the temptation to feel as if we are selling out by collaborating with nonarchaeologists in the teaching of archaeology and history. Teachers are professionals in their own fields and welcome us for the rich content we can contribute to their teaching. In the case of MayaQuest, the use of computer technology helped us achieve this partnership.



The Technology Coordinator's Perspective

With the wealth of resources available on the Internet, how do teachers find projects like MayaQuest and integrate them into their curriculum? The best Internet applications are made up of unique partnerships. For MayaQuest, the Internet provided a means to mediate communication on behalf of the kids, the team, and the scientist, whose input was essential in raising the students' level of learning. One student's reaction last year was: "Having David Friedel respond to our question was like getting batting practice from Babe Ruth."

We now have the opportunity to forge strong partnerships between K-12 education specialists, experts in the field, and informal education centers (e.g. museums, zoos). By adding this additional layer to the schools, science centers, and the field professionals, we not only forge new alliances but justify their existence. How can scientists warrant the additional time required to expand their work to include K-12 education? What better way than to have an audience of students who are not only engaged in the study of these professionals, but also advocating informally for more and broader participation at a public level. In an interview with Maya expert Linda Schele, she declared that MayaQuest did more to attract kids to the field than all her book sales and lectures in the past 25 years.

One of the problems with the Internet is its creation of a certain infatuation with the technology itself. We are now seeing a tremendous amount of information being generated with an over-use of the technical bells and whistles. Fortunately, we will reach a time when these technologies will become common-place, like the telephone, and then the effective use of the Internet will be easier to measure. In the meantime we need to be diligent and critical consumers of the resource and the information, and ask ourselves, "Is this improving student learning"? If we cannot answer yes, then there is no need to force its use.

With MayaQuest, kids became connected with another culture. They realized that the people in Latin America had a rich culture history before

Columbus. They saw connections between environmental degradation and cultural decline. They experienced a myriad of ways to learn about issues and they saw that experts don't always agree. They wrestled with ethical issues and clarified their own values. What conclusions could archaeologists and educators draw?

Part of the assessment of these projects will need to take place in 15-20 years. Will we look back at this time and be able to identify professionals in scientific fields whose first introduction was a participation in MayaQuest or similar project? If we answer yes, then the value of these activities can certainly be measured. Will we be able to look back in 20 years and identify cultural shifts in peoples' attitudes towards supporting the sciences? If we can answer yes, then these efforts have not been in vain.

The Educators' Perspective

MayaQuest 1995 - The year we threw out the textbooks and traveled to the remote regions of Central America without leaving the classroom; a year for magic and incredible insights. By participating in the MayaQuest Project, we learned that our students had an insatiable hunger for knowledge and they were dying for us to fill them up. But first we had to get their attention.

In February, several teachers embarked on a three month expedition throughout Central America. We brought with us 300 1st, 2nd, 4th and 6th graders from Como Park Elementary School in St. Paul, Minnesota. It wasn't the usual travel adventure; we didn't get bug bites, sunburn or even Montezuma's Revenge. What we did get was an opening into the world of the Maya culture through an on-line adventure called MayaQuest.

Our goal was to have the kids experience the sights, sounds, food, history, and people of the Maya civilization in the same way the team did, except we stayed in Minnesota. One hundred fifty teachers-strong, we were able to simulate a Maya community by using Maya arithmetic in our math class, building a rain forest with authentic birds, plants and animals, deciphering hieroglyphs, and writing Maya-style

poetry. The beauty of this experiential style of teaching is its virtually painless application. Students hardly realized they were "learning," because they were too busy discovering and trading information.

One of the most gratifying aspects of this program was watching these young minds come alive with their own imaginations. The kids learned about Mayan culture, and that learning triggered an unbridled range of theories pertaining to Mayan life-and death. For instance, a great enthusiasm arose from discussions on why and how the Maya civilization collapsed. Some said it was due to famine or disease, while one student believed it was due to alien abduction. Wild hypothesizing, yes, but it let us know that these kids were thinking imaginatively. They were synthesizing information; using the facts they'd learned as a foundation for creative thinking of their own.

How did we pull this off while staying within our curriculum? By using a little creativity and thinking in the most untraditional ways possible! We turned our classrooms into living labs for discovery every day. As a collaborative effort among teachers, we built a school-wide curriculum centering on the Maya culture. It covered the basics of readin', writin', and 'rithmetic, but we went far beyond that to cover a wide variety of other disciplines, including math, science, geography, art, architecture, history, anthropology and archaeology. It was clearly an experiment that worked for us!

Lots of kids, for instance, have a tough time with math, and many are not at all interested. Not so during these three months! The students were thrilled to learn how the Maya figured things out in their mathematical base 20 system. Once the kids were comfortable with the numbers, they converted their classroom numbers with the three Mayan symbols: the shell, the bar, and the dot. Soon all the classrooms had Mayan numbers on their doors. The converting process was a big hit. Students began converting their birthdays and telephone numbers to Mayan numbers.

The students also did a lot of reading, but not from the most conventional sources. One sixth grade

special education class became the experts at deciphering hieroglyphs. Not only were the students able to read the glyphs, they were able to create their own personal stories through them. With a color printer, they designed frameworthy reproductions of these glyphs, which they posted all over the school. This same industrious group, with the help of a skilled teacher and carpenter, designed and built a six foot tall majestic Maya Ruin in honor of the site, Tikal.

Meanwhile, sixth graders corresponded, through MayaTalk on the Internet (the MayaQuest Listserv), with students all over the globe, from Australia to Belize. Before and after school and during recess, the students visited the computer resource center to gather clues about the ancient Maya.

We had to take risks, such as the decision to abandon our textbooks and hide our work sheets. The students enjoyed the risks; they were thrilled with the connections they made with an ancient civilization, but more importantly, the connections they made with each other. The learning was not traditional; it was serendipitous. The students were the explorers; we just gave them a little guidance finding their own path.

Resources:

- MayaQuest <http://www.mecc.com/mayaquest>
 Society for American Archaeology <http://www/saa/org>
 TimeTraveler <http://id-archserve.ucsb.edu/timetraveler/main.html>
The Maya. Lawana Hooper Trout, Chelsea House Publishers
 ISBN 1-55546-714-8
The Ancient Maya. 5th ed. Robert J. Sherer. Stanford University Press ISBN 0-8047-2310-9



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AnthroNotes has a three part mission:

- 1) to more widely disseminate original, recent research in anthropology in order to help readers stay current in the field;
- 2) to help those teaching anthropology utilize new materials, approaches, and community resources, as well as integrate anthropology into a wide variety of curriculum subjects; and
- 3) to create a national network of anthropologists, archaeologists, teachers, museum and other professionals interested in the wider dissemination of anthropology, particularly in schools.

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