Yale Peabody Museum of Natural History:

Tree of Life Visitor Study

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September 2006

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Executive Summary

A front-end evaluation for the Yale Peabody Museum's developing "Tree of Life" exhibition was conducted to get a sense of how museum visitors interpret phylogenetic trees. In particular, seven ideas were tested: (1) Visitors' preconceptions about the Tree of Life; (2) The ways visitors read conventional scientific Trees; (3) Visitors' selection of the most appealing Tree among a choice of three Trees; (4) Visitors' ability to resolve the relationships between certain organisms using Trees; (5) Visitors' perceptions of the ways scientists use the Tree of Life; (6) Visitors' perceptions of the Tree's practical applications; and (7) How visitors might use an interactive Tree of Life. Several methods were used to gather data for this study, including interviews and focus groups at the American Museum of Natural History and the Yale Peabody Museum.

Findings

It was apparent that many people interpret the expression, Tree of Life, as a vague ethical or environmental concept relating to biodiversity, the ecosystem, conservation or to the Tree of Life in Disney World. Although the expression seems to have strong environmental implications for many of those questioned, the Tree of Life is not always recognized as a scientific construct. It emerged that very few respondents thought of the Tree of Life as a cladogram.

Several common trends occurred as visitors attempted to interpret scientific trees: misreading of the long branch as being an evolutionary timeline culminating in the end-product at the far-right of the Tree (and an associated idea that the Tree is *about* that species); misinterpretation of the order as a ladder of progress and the related misunderstanding of humans as the most evolved species on the Tree; uncertainty over the significance of branch length; and confusion about the coexistence of both extant and extinct organisms on the Tree.

The majority of respondents found Tree #2 (Appendix 2) the most appealing and the easiest to understand; it also did the best job of representing each clade as having shared characteristics.

In determining the relationships between various species—dinosaur, caiman and parrot; fungi, plant and elephant; and five plant species—visitors used their prior knowledge to determine the relationships, as well as superficial characteristics they noticed in the images (Appendix 3). Once shown the related Tree, however, respondents could work out the relationships between species.

When asked what evidence respondents thought scientists use to create Trees, the most frequent response was genetic material or DNA, followed by physical evidence such as bone structure.

Most people could not think of practical uses for the Tree of Life. They believed the primary purpose of Trees was simply advancing science and scientific knowledge.

People are interested in learning about a diverse range of things from an interactive Tree of Life, from topics relating to evolution to information regarding specific species (such as T. rex).

Our findings suggest some rather important gaps in visitors' approach to the Tree of Life concept. Although many visitors feel familiar with the expression, Tree of Life, or even with scientific Trees themselves, misconceptions abound about how they are constructed, how they should be read, and how they could be used by science and society. A museum exhibition about the Tree of Life will require easy-to-read labels (with interpretive keys) explaining how to read a Tree, the Tree's value to science and society and its potential practical applications.

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Introduction

This front-end analysis for the Yale Peabody Museum's developing exhibition on phylogeny (Tree of Life) aims to get a sense of how museum visitors imagine and interpret the scientific "Tree of Life" (herein referred to as Tree.) In particular, seven primary ideas were tested:

- Visitors' preconceptions about the Tree of Life (pages 2-5)
- The ways visitors read conventional scientific Trees (pages 5-9)
- Visitors' selection of the most appealing Tree among a choice of three Trees (pages 10-13)
- Visitors' ability to resolve the relationships between certain organisms using Trees (pages 13-14)
- Visitors' perceptions of the ways scientists use the Tree of Life (pages 15-16)
- Visitors' perceptions of the Tree's practical applications (pages 16-18)
- How visitors might use an interactive Tree of Life (page 19)

Methodology

Several methods were used to gather data for this study:

- Some 39 interviews with 59 museum visitors at the American Museum of Natural History in the Hall of Vertebrate Evolution, on July 8 and 9, 2006. (There was also a pilot study of AMNH visitors conducted on June 29th.)
- A focus group with teachers and a focus group with high school students participating in an AMNH Tree of Life Summer Institute, both held on July 10, 2006, the first day of the institute, during the lunch break.
- A one-hour focus group with middle school students participating in a Peabody Museum summer camp program, on July 19, 2006.
- A one-hour focus group with the campers' parents at the Peabody Museum, also on July 19, 2006.

The data collecting instruments are included in Appendix 1. Note that the interview instrument was used as an outline for the focus groups. The Trees used in interviews and focus groups are included in Appendix 2. The images used in interviews and focus groups are included in Appendix 3. Demographic data for all samples can be found in Appendix 4.

Findings

The following findings are presented according to the seven research interests listed above. The various respondent samples are incorporated where relevant to the discussion; the majority of data comes from the Peabody Museum focus groups and the AMNH interviews.

Preconceptions of the Tree of Life

The first question we asked respondents was,

- When you hear the expression "Tree of Life," what comes to mind?

We also asked the campers and adults in focus groups at the Peabody Museum to draw the images that came to mind. (Tree of Life Institute participants were not asked this question because we assumed they were familiar with the expression.) Subsequently, we asked respondents who had not mentioned *scientific* Trees:

- Have you heard the term used in science (or biology)?

We also asked:

- Is the Tree of Life finished? Or is it still growing?

AMNH Visitor Interviews

Only 29% of interview respondents' top of mind association with the Tree of Life had something to do with evolution or the interrelationships of species. There were four people who said that the Tree of Life is used in science without explaining how it is used. Although it was the most frequent association, fewer than 1 in 4 respondents mentioned the word "evolution" specifically. Figure 1 illustrates interview respondents' first associations with the term Tree of Life. (The responses designated as "Other" were irrelevant or unintelligible.)

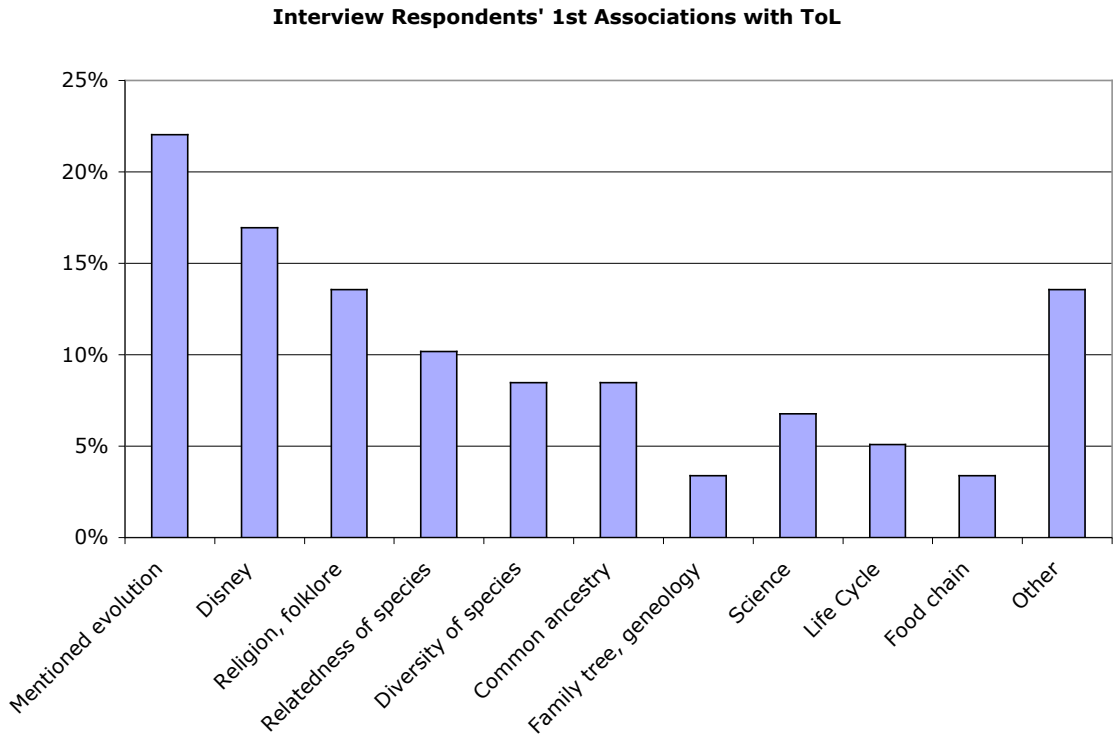
Visitors referred to evolution in their responses in the following ways:

Evolution, animals branching out, natural selection, branching off species.

Evolution, common ancestry, relatedness.

Keep in mind that all the interviews were conducted in the AMNH's Halls of Vertebrate Evolution, where every text panel and label contains a Tree as part of the interpretation of the species on display. However, only one respondent recognized the Tree as something she had seen in AMNH's Orientation Center; none of the other visitors made reference to the displays they had been touring.

Figure 1



The second most frequent association in the interviews (17% of the respondents) was Disney—either the Tree in Walt Disney World or the Circle of Life popularized in Disney's Lion King. Some 14% of respondents thought of religion or folklore when they thought about Tree of Life. Examples are, "The Tree in the Garden of Eden," "Mother Nature," The Bible, Adam and Eve."

Some 10% of the respondents thought Tree of Life referred to the relatedness of species and 8% said the Tree referred to the common ancestry of all species. For example:

> *[It's] a symbol to explain where we came from; one point begins everything, like a tree it has branches.*

A number of respondents thought the Tree of Life referred to the diversity of species, both extant and extinct, but it was unclear if they thought of the ways species are interconnected.

> *[Tree of Life refers to] all different types of animals in the world going back in time.*
>
> *All life forms that existed.*

PMNH Focus Groups

From focus groups, it was apparent that many people interpret the expression, Tree of Life, as a vague ethical or environmental concept relating to biodiversity, the ecosystem, conservation or the *circle of life*. Although the expression seems to have strong environmental implications for many of those questioned, the Tree of Life is not always recognized as a scientific construct (even with the bias of interviewing within a natural history museum). The Tree of Life is sometimes interpreted as a religious expression (particularly as the term does refer to concepts in Judaism and Christianity). In one instance, a PMNH student related the phrase to the Tree of Life in Bangalor, India.

For many, the Tree of Life just literally calls to mind a Tree, so that people may recall an image of a Tree seen knitted on a sweater or on a ceramic dish. A surprising number of adults and campers referred to the Tree of Life in Walt Disney World, something many had actually seen firsthand. All PMNH campers seemed to have heard the expression, Tree of Life (though there may have been some group dynamic at work). However, as mentioned, often they imagined the Tree of Life as something other than a scientific cladogram. For example, they described their individual drawings as:

> *I'm drawing a Tree that has a chance to live for a really long time if you don't pollute it [and you] try to prevent it from getting any environmental destruction.*
>
> *My Tree of Life is an environment kind of thing. I'm going to draw it so it's the only thing alive and it'd be what would happen if you cut down all the trees.*

One camper's Tree represented "mother nature" with a smiling face in the treetop and two outstretched, branching arms. Another depicted a tree with five human-like figures growing where branches would be. One camper, however, did draw a cladogram or scientific Tree with "bacteria, viruses, fungi, rhinoceros and plants."

The PMNH adults expressed a range of responses from the scientific to the cultural. An example of a semi-scientific description:

> *When you say Tree of Life what comes to mind is the imagery of a tree with each branch being some type of organism, different kinds of plants and animals, seeing how they're all related to one another but in their distinct groups as well.*

Another parent's comment illustrates the diversity of images that can come to one person's mind:

> *[I imagine] different divisions of trees: family trees, fairy tale ideas of trees, trees as the beginnings of life, the Tree of Life, very old trees in arboretums that you can look at and find their ecological system.*

Another participant reveals the ways the notion of a Tree of Life may be imbued with a sense of order or hierarchies. She imagines the Tree of Life as illustrating how:

> *...everything is interconnected from lowly microbes to birds in the sky, sort of like the food chain but more than who eats who….*

Scientific Trees

When interview respondents and focus group participants were asked if they had heard the term, Tree of Life, used in science, the vast majority said they had. However, it later emerged that few of them thought of the Tree of Life as a cladogram. The use of such a common and accessible expression, Tree of Life, may actually lead to more confusion than clarification: museum visitors may assume erroneously that they know what it means.

When questioned about whether the Tree of Life is still growing or complete, the great majority of respondents do understand that the Tree is still growing (though the question itself may have been "leading" and implied this). Several people mentioned that it's growing because new species are still being discovered. Interestingly, a few people mentioned that humans are creating new species through gene manipulation.

Reading the Tree of Life

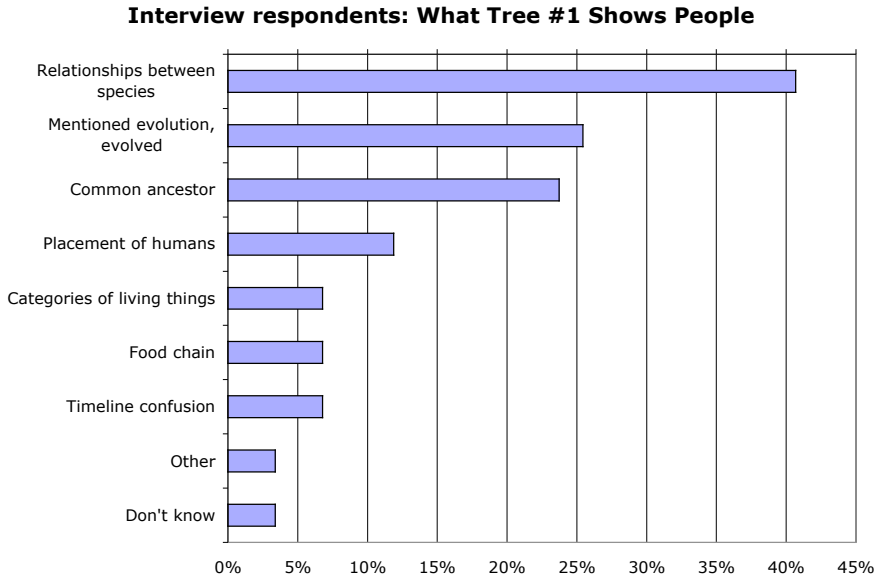
After assessing visitors' first impressions of the Tree of Life, we showed respondents an example of a scientific Tree, and encouraged them to read and interpret the diagram (See Tree 1, Appendix 2). We asked:

- What would you say it's supposed to show people?
- What does the Tree suggest, if anything about relationships between species?
- What is the significance of each node or branching point?

Interview respondents

Some 69% of the interview respondents recognized that the Tree shown to them depicted something related to evolution. One person commented, "I understand the idea, but didn't understand the term, Tree of Life." Figure 2 illustrates the concepts they mentioned when interpreting the Tree.

Figure 2



The most frequently mentioned topic was the relationship between species or their interconnectedness (mentioned by 41% of the respondents), for example:

We have bonds in common if you go back far enough.

How species evolved and how they're related.

How all forms of life are connected.

More than 1 in 4 respondents specifically mentioned an aspect of the word, evolution in their explanation of the Tree:

[It shows] how species evolved and how they're related.

Evolutionary branches, everything came from a point of origin, a single cell, and branched off.

A number of respondents (24%) read the Tree as showing species' common ancestry.

[It shows] we all came from the same origin; everyone has evolved from the same thing.

All [species] come from one place, evolution not creation.

Some 12% of the respondents expressed confusion about the placement of humans on the Tree. Several of them tried to understand how the Tree could be interpreted to illustrate human superiority, or why humans were placed on the same level as the hare.

[The Tree shows] the differences between species. Why are the human and hare together?

It's weird where humans fit.

[The Tree shows] relationships: humans are in the middle, ancient or extinct shark and T. rex [are on either end].

Some visitors interpreted the Tree as "diversity," illustrating the categories and types of species that exist or existed:

[The Tree shows] various types of life forms from present day back to the age of dinosaurs, the different types that exist: reptiles, amphibians, birds, mammals and extinct reptiles.

Some respondents thought the Tree looked like a food chain. Other visitors wanted the Tree to relate to time or a timeline of evolutionary history, for example, "[It's a] timeline: T. rex is the oldest, parrot is after, caiman [is after that and so on]"

PMNH Focus Groups

Once focus groups participants were shown an example of a scientific Tree, they remembered having seen it in previous science education or museum exhibitions. Some of them recalled Trees as being about human evolution, or in relating to "anthropology." Both PMNH parents and campers had trouble working out the order of the species on Tree #1. PMNH parents had the following comments about the Tree:

> *I was trying to think of it as the progression of evolution but it doesn't really look like that because T. rex is up there so that's a little confusing.*
>
> *[This represents] species that have somehow dead-ended or at least we don't know the progression of evolution.*
>
> *You either have to have only things that exist now or you have to have a timeline.*
>
> *The order is confusing.*

As suggested by the last comment, the PMNH parents were very confused by the order in which species are depicted on the Tree. They debated various explanations, even that the order represents land animals, water animals and air animals. The following comment is one PMNH camper's attempt to interpret or read the Tree:

> *I was thinking that it goes up to the point where it stops evolving, so the last point is the most recent and that's kind of where it's stopped for now and you can't see much difference. So T. rex was wiped out so that was the last point of the dinosaurs because they couldn't evolve any further. And that's just where it stopped. You can't see it changing any more. The most recent point of the species is at the top.*

Generally, respondents wanted to read from the oldest species on the Tree to the most recent, from left to right. As one PMNH parent comments, "We're used to reading left to right so that's the progression we're looking for if it is horizontal." The length of the line was also confusing for parents:

> *The branches I understand but the other lines are confusing.*
>
> *I guess we're saying the timeline is confusing.*
>
> *Why is the shark line so long?*
>
> *The eye assumes that the length of the line is of some importance.*

After being shown Tree #1, participants became preoccupied with reading the long branch of the Tree as an evolutionary timeline, with clear implications of evolutionary progress towards specific present-day goals. More specifically, there is often a misconception that the long branch of Tree #1 represents the evolution of the final product, T. rex, with each species branching off as it evolved. Respondents assumed, then, that the Tree was *about* T. rex. Similarly, T. rex was interpreted as the endpoint of dinosaur evolution or the last phase in dinosaur evolution. Because of this interpretation, respondents also occasionally expressed bewilderment that an extinct species would be at the end of a timeline:

> *To see a dinosaur up there is confusing given that that is the ultimate path.*

Even though the Tree does not position humans at any one "end" (to the far left or far right), visitors still tended to read it as being about human evolution, or in representing humans at the center or top of evolutionary progression. For example, people have read the Tree as moving in time from T. rex to human, and shark to human, to explain humans' place at the center or pinnacle.

Although one PMNH parent liked the placement of humans on the Tree, one PMNH parent questions:

> *What is confusing is that its horizontal and we're used to seeing a more vertical progression with humans at the top and lesser mammals, birds, reptiles, dinosaurs [lower down]… Having them all on the same line is a little visually distorting. It looks like, OK, if we're starting with dinosaurs on this line, then obviously birds branched off, reptiles branched off, mammals, they all branched off of that line is what the picture is looking like. What's confusing is visually you see the shark first with a very long line but does that indicate that the shark deviated from the family branch first or has the shark been around the longest? That's ridiculous*.

Tree #1 conveys concepts of species relatedness and common origins. But how much do people really comprehend about *how* species are related? When prompted (somewhat leadingly), "does the Tree suggest anything about the relationship between species?", 9 in 10 respondents said it does. However, upon closer examination, it appears that although scientific Trees may seem familiar to many visitors, often they misread them or find them confounding.

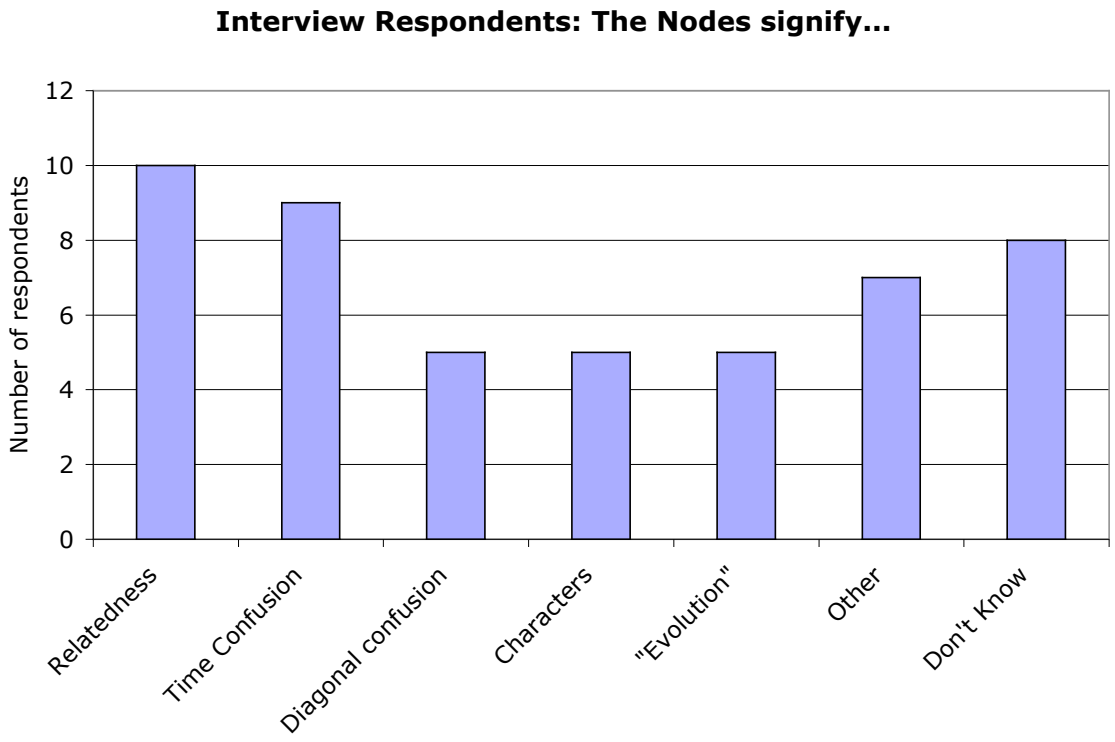
Overall, our study identified several common trends that occurred as visitors attempted to read/interpret the first scientific Tree we showed them (Tree #1): misreading of the long branch as being an evolutionary timeline culminating in the end-product at the far-right of the Tree (and an associated idea that the Tree is *about* that species); misinterpretation of the order as a ladder of progress and the related misunderstanding of humans' placement on the Tree; uncertainty over the significance of branch length; and finally, confusion about the presence of both extant and extinct organisms on the Tree.

The Nodes: Interviews

Interview respondents' ideas about what the nodes or branching points signify on Tree #1 indicate the extent of confusion about Trees. Only 12 people said the nodes signify the point of divergence where speciation took place, and only 5 people said the nodes represent the physical character that the branches have in common. In response to the question, just 5 people mentioned evolution and 10 people talked about relatedness of species, but none of those 15 respondents appeared to understand the salient idea about the nodes.

Again respondents expressed confusion about the diagonal branch leading to T. rex and the sense that the Tree represented a timeline. Labeling the character or feature at the node may help to clarify its significance. Figure 3 illustrates interview responses about the meaning of the nodes or branching points.

Figure 3



Nodes: PMNH focus groups

When asked the significance of the nodes or "branching points" in focus groups, PMNH campers correctly identified them as representing the "common ancestor" or "where they split off, at that point that's where they started changing." Also, when asked whether according to the Tree, is human or hare more closely related to the T. rex, one PMNH student realized they were interchangeable.

The Peabody parents were less certain of the significance of the nodes than the students. The question led to continued consternation over the length and significance of the branches. One parent, on the right track, commented:

> *Whatever the original thing is on the very bottom, [the node is] when they started to branch off and become more specialized… so [it signifies] where they branched off from the original organism*

Comparing Graphic Representations of Trees of Life

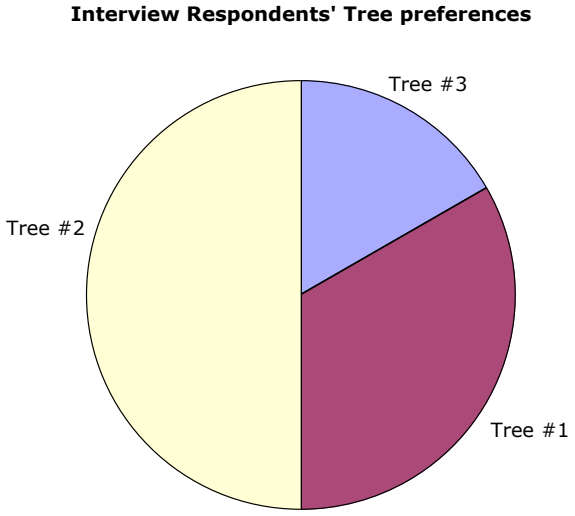
An exercise probed the ways visitors read and interpret different representations of Trees. We asked visitors to compare the first Tree they'd seen (Tree #1, Appendix 2) with two additional Trees (Tree #2 and Tree #3, Appendix 2). We then asked:

- Which Tree do you find easier to understand? Why?

Interviews

Generally, interview respondents found Trees #1 and #2 the most useful and familiar and the circular Tree, #3, most difficult to read and unfamiliar. The majority of respondents found Tree #2 most appealing and the easiest to understand (see Figure 4 below). Tree #2 also seems to do the best job of representing each clade as having shared characteristics. Tree #3 is deemed largely incomprehensible.

Figure 4



Tree #1

Interviews

Some interview respondents found Tree #1 the most appealing (it was also the first tree respondents saw and the tree they spent the most time with). Interview respondents commented:

#1 is simpler, easier to see; it makes things look more connected.

#1 is just in a straight line with everything coming off it.

If you're trying to show chronological order, I like #1.

However, as comments make apparent, even though some respondents preferred Tree #1, this did not mean that they were reading it correctly (as discussed earlier).

PMNH Groups

Some of the students and adults preferred Tree #1 because it better illustrated that all the species shared one common ancestor. PMNH students liked Tree #1 because

> *It kinda moves up. It starts low and moves up. When you get closer to humans… that's higher up. So it seems to me that the higher up, the most recent.*
>
> *You get the impression that the shark and stuff are just coming off of [the main line].*

Tree #2

Interviews

Many interview respondents found that Tree #2 best illustrated the shared relationships between species. They commented:

> *[# 2] seems so much easier, more logical, spatially more structured.*
>
> *In #2 you can see relationships easier: T. rex and parrot, human and hare.*
>
> *#2 gives a better view on which species are more closely related.*
>
> *#2 is like a sporting bracket. It's confusing because they're all going down but if you flipped it, it'd be more like a family tree.*

Comments illustrate lingering bewilderment about how time is represented on the Trees:

> *#2 doesn't look like evolution of man; why is T. rex at the end if it came first?*
>
> *If you're trying to show chronological order, I like #1, but #2 is the best as a drawing.*

PMNH groups

Interestingly, many PMNH adults found both Trees #1 and #2 confusing because of their inability to understand the implicit organizational rationale. Even when contrasting the two Trees, respondents still often misread the species as being endpoints of lineages rather than representatives of lineages.

When we asked respondents to consider aspects of the Trees independent of evolutionary time, #2 emerged as a good illustration of species relationships. A PMNH adult stated:

> *#2 shows the relationships more clearly because you have this u-shape which shows that there is a relationship between the bird and the dinosaur and to some extent the reptiles have a clear relationship to the caiman. It delineates the relationship a little more clearly.*
>
> *I like #2 better than #1 because in #1 the lengths are confusing; in #2 it doesn't bother me so much if this [line] is longer than this because you're trying to get at the relationship and the length is not supposed to be meaningful.*

One PMNH camper commented:

> *I like the one with the square brackets better because you can see the branching off better, the split more clearly. [#2 is best] because in [#1] it looks like T. rex is just on one line and [in #2] they're all branching off of each other.*

Another PMNH camper reveals another way time misleads the novice Tree reader. The quote also reveals underlying Homocentrism:

> *I like [#2] because you can make out who's been there longer. The human and hare are mostly the same out of all the species shown on this paper. It shows how recent each is. The most recent one is in the center and then they all branch off.*

After seeing Tree #2, Tree #1 is read by one PMNH camper as problematic because:

> *Also with #1 the T. rex goes up that line and it kinda makes you think it's the original thing. But there on [#2], it starts at the very bottom, but as it goes up you can see that they change. But with T. rex on the main line in the first one, it looks like T. rex was the first thing and everything evolved from it.*

Tree #3

Tree #3 was the last Tree we showed, and also the one deemed least comprehensible and most unfamiliar. Overall, interview respondents and PMNH focus group participants who liked Tree #3 did so because it "looked interesting," not because it was clear and understandable.

Interviews

An interview respondent states:

> *#1 and #2 are similar, not a lot of difference relationship-wise. #3 is harder to know where it starts.*

And a typical comment about #3:

> *#3 is confusing: I can't tell the beginning from the end.*

A thoroughly confused visitor states:

> *[I am] clueless about all of them, I need more information on them. They don't make sense [to me]. #3 is esthetically better.*

PMNH groups

Most PMNH adults thought Tree #3 was confusing or messy, sometimes because of the proximity of T. rex and the shark. Some of them though it might work if it were presented flat on a table or floor rather than on a wall. One Peabody parent expressed frustration with all the diagrams because:

> *When I think of Tree of Life, I think of plants too and I know this is only a sub-sample but you kinda want to see that.*

AMNH Tree Institute participants

The AMNH Institute respondents' comments were particularly valuable in comparing and contrasting the three Trees. The AMNH students had a very good grasp of the information represented by Trees (we were later told that they had completed a course on Tree thinking at the Museum). Only one of them misread the circular Tree (#3) as moving from oldest species to most recent. One student said sagely, "The Trees don't really tell the time period. They just show relationships."

Like the Peabody parents, the teachers expressed a lot of frustration about the ways they thought time was reflected in Trees (or the ways in which it was not). Their prior knowledge suggested that the length of the branches should reflect the relative length of evolutionary time (particularly in the long main branch on Tree #1). "We've been conditioned to think about time."

While institute participants, both students and teachers, were far more cognizant of the meaning and use of Trees, they did not do particularly well on a quiz administered to all participants on day 1 of the institute. The quiz, "Basic Tree Thinking Assessment," developed by David A. Baum, Stacey DeWitt Smith, Samuel S. Donovan, "includes a number of multiple-choice questions you can use to test yourself on your ability to accurately interpret evolutionary trees." Both teachers and students got only 50% of the questions correct on average. The quiz is available online at www.sciencemag.org/cgi/content/full/310/5750/979/DC1.

Incidentally, some of the quiz items could be built into an interactive game that could teach museum visitors and online users how to read trees. As discussed below, the game approach was suggested as an appealing format to teach Tree thinking by several respondents in each of the study samples.

Resolving Species Relationships Using Trees

A series of exercises probed the ways visitors worked out the relationships between certain species: the relationship between dinosaur, caiman and parrot (shown first); between fungi, plant and elephant (shown second); and between five plant species (shown last). (See Appendix 3 for images and relevant Trees.) We asked:

- Which of these species would be more closely related on the Tree of Life? Why?

Then after the choice had been made, we showed the associated tree and asked:

- Does the Tree change what you thought? Why?

To answer the question, visitors used their prior knowledge about the relationships between certain species, as well as superficial characteristics they noticed in the images. Once shown the related Tree, however, respondents could work out the relationships between species as depicted on the Tree.

Overall, in hindsight, we recognized that the question was not very productive. It did not invite conversation, and people often suspected us of trying to trick them. For example, after misidentifying the first pair of closely related species, many respondents said they would choose the most unlikely pairing from the second set, for example, "Fungi and animals are counterintuitive. But I chose the obvious one last time [and got fooled]."

Interviews

Interview respondents were shown the T. rex, caiman and parrot image first. We expected these visitors to have no trouble recognizing T. rex and parrot as more closely related since they were touring the Halls of Vertebrate Evolution at AMNH and could see cladograms on every label deck, including some linking birds and dinosaurs. We also suspected all respondents would recall seeing the T. rex and parrot linked on Trees #1 and #2. Still, most respondents said the dinosaur and caiman were more closely related. One

respondent reasoned that the parrot and caiman were more closely related because, "They still exist but the dinosaur is extinct." One respondent who selected bird and dinosaur said:

Don't a lot of dinosaurs have bone structure for flying?

Some interview respondents were stymied about why fungi were more closely related to animals than plants:

To me, they both grow in the same environment. I associate them. Plants have seeds, fungi have spores, but this is more a layman's way, not how scientists do it.

It's surprising: fungi look more plant-like.

Interview respondents rarely chose the more closely related plant pair (tomato and sunflower) from among the 5 plant species. Their reasoning highlights how counterintuitive Tree thinking can be for the non-scientist.

Pine and sunflower [are closest] because of the way they sow their seeds.

Pine and magnolia because they both grow on trees.

PMNH Groups

The majority of the Peabody focus group participants were aware of the close relationship between birds and dinosaurs. However, one PMNH student pointed out what she believed to be obvious: "T. rex and caiman are reptiles." (She also later described T. rex as a "big lizard.")

In focus groups, there was more of a consensus about the close relationship of fungi and animals. Again, this seemed to be related to respondents' prior knowledge. A PMNH camper said:

Our teacher told us [fungi] don't do the same thing that plants do, they can't make their own food.

You kinda gave it away when you said it's not always what meets the eye: it seemed too easy for fungi and plants to be related.

To resolve the relationships between the five plant species, a lot of focus group respondents used seeds and flowers as evidence (and perhaps misleadingly, the tomato flower was not depicted, only the fruit). Some guessed based on what "just seems right." Some PMNH campers classify in the following ways:

Pine cones and sunflowers because they both have seeds and how they grow.

Magnolia and carnation because they're both simple flowers.

Tomato and sunflower because they're both producing seeds and they're edible.

We encountered some homocentrism when visitors worked out the relationships between these species based on the Tree. As seen above, people sometimes categorized the relationship between organisms by their connection to humans ("We eat these").

Understanding Scientists' Evidence

We asked interview respondents and focus group participants to consider the evidence scientists might use to construct a Tree.

- How do scientists figure out how thing are related? What kind of evidence would have given rise to this Tree?

Interviews

When asked what evidence they thought scientists might use to create Trees, the most frequent response in interviews (34% of respondents) was genetic material or DNA (see figure 5). Apparently the public believes that new technological advances make analyzing and interpreting evidence from DNA a relatively simple process. The second most frequently mentioned source (30% of the respondents) was physical evidence: looking for patterns of similarity in bones and other structures. Several people cited evidence from environmental factors, fossils and time. A number of respondents offered more than one type of evidence, for example:

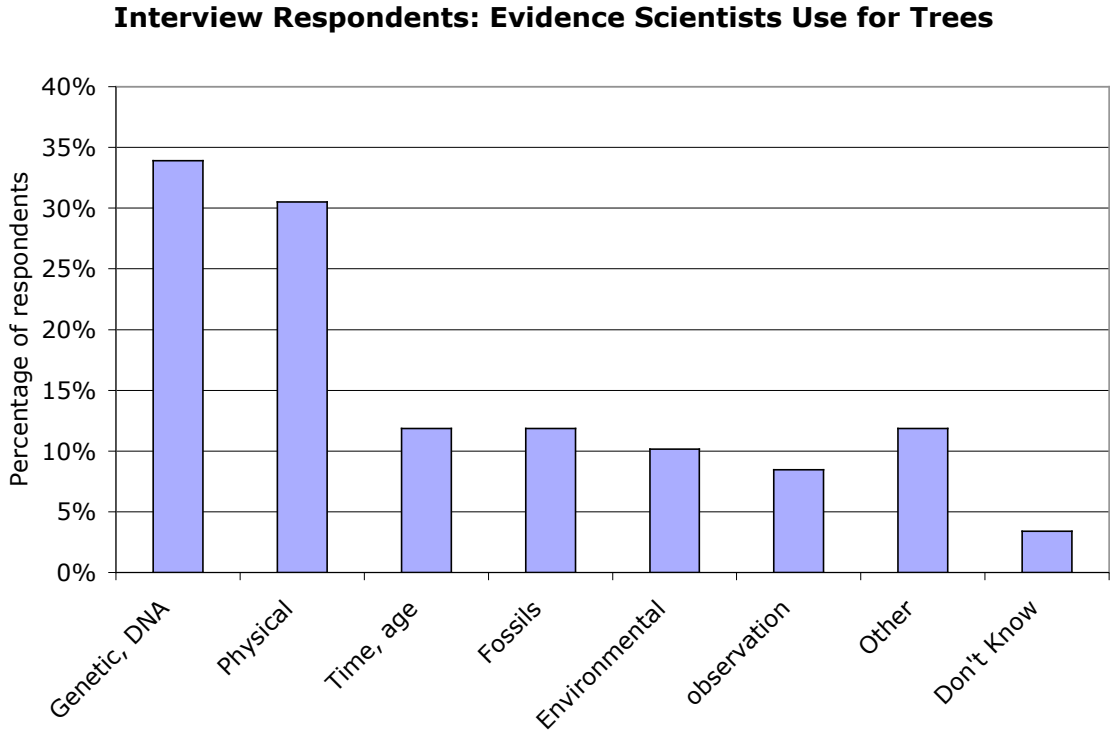
Fossils, DNA, chemical processes.

What came first, what can possibly be related: DNA, genetic categories, genome, family tree of animals.

Fossils, chemicals, physical evidence, mathematics: all together.

Chemical analysis, fieldwork, contemplation.

Figure 5



PMNH and Institute focus groups

The participants in the PMNH focus groups specified fewer examples of scientific evidence than did interview respondents (perhaps because relatively not a lot of time was spent on the question). However, parents and campers did identify a wide range of data that might be useful to Tree-building. PMNH parents said:

> *Bone structure, where they're from and what they did and they're habits.*
>
> *Modern science is relying more and more on genetics because it's so much more accurate.*

The Peabody students came up with a range of seemingly forced responses:

> *Fossilized carbon dating.*
>
> *Bone structure and physical similarities. There's not much else you can do because [with] dinosaurs, what you see is what's there.*

The AMNH teachers from the Institute also expressed some uncertainty about the types of data that go into making Trees ("phylogenetic vs. morphological"). It may be worth emphasizing in the proposed exhibition that Trees change with accumulating data, that no Tree is definitive and that morphological data can go into making phylogenetic Trees.

Practical Applications

Two questions probed visitors' sense of the practical applications of Tree thinking:

- What are some ways scientists and society could use this knowledge?
- If you could access an interactive Tree of Life on the Internet, what would you want to look up or learn about? What questions do you have?

Interviews

Most people could not think of practical uses for the Tree of Life: they were stuck on simply advancing science and scientific knowledge as the primary purpose of Trees. Just 1 in 5 (22%) of the interview respondents could imagine any practical value in Tree thinking, including all of the following: improving the food supply and agricultural uses (7%); medicine and cures for diseases (5%); understanding humans place in nature and human evolution (3%); understanding intra-human connections (3%). Figure 6 illustrates the interview responses.

Respondents recognized that Tree thinking could lead to advances in science, such as in understanding the interconnectedness of living things and their origins; predicting the future of species, and the future evolution of lineages; and advances in bioengineering and DNA research. Some of these advances were also recognized as potentially beneficial to human life.

The following are examples of practical applications suggested in interview responses:

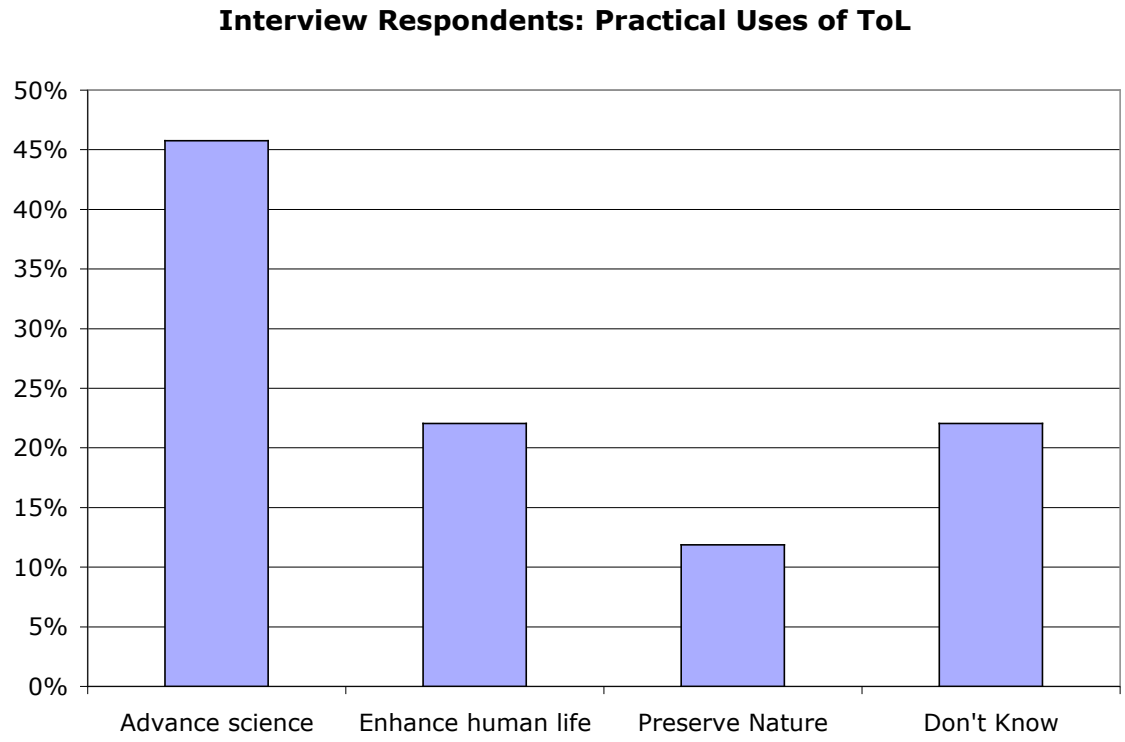
> *Diversity and evolution makes life better. The food we grow, crops, understanding how they evolved to maintain the food supply. The whole ecosystem: plants, animals and insects—their role.*

[Trees can show us how] to preserve the future, learn from the past.

The history of man, how we evolved as a people, common threads.

[Trees show] we all come from one thing. It's good to grasp that early on.

Figure 6



A few respondents were quite knowledgeable about the potential practical uses of Trees:

Medicine, antibiotic resistant bacteria, genetic relationships; global warming, conservation of biodiversity, losing relatives.

In bioengineering, DNA, immunities, medicines.

Like the tomato sunflower connection: people who grow one could use what works to grow both.

Understanding the process of how an organism works should help with others; fungi and elephant, sunflowers and growing tomatoes. Could you predict how they would evolve?

To show people that it's not linear thinking, not a timeline, things don't happen linearly.

Among interview respondents, a group of four biology teachers suggested that Trees could be used to discuss artificial selection, a notion that contributed to Darwin's conclusions about natural selection. They also suggested having students create their own animal, supported by characters on a Tree of their own invention.

This young college-bound respondent certainly had ambivalent feelings about Trees and what they tell us about evolution:

> *It helps to know where we came from. I don't believe we evolved from monkeys. [That's] where animals came from.*

PMNH and AMNH Groups

Unfortunately, none of the young people (PMNH campers and AMNH Institute student participants) could see much value in scientific Trees. AMNH Teachers had a strong sense of the practical applications of scientific Trees. They thought it would be very valuable to use Trees in teaching to illustrate conservation and the relationships between humans and endangered animals. They also mentioned medicinal purposes, such as "curing cancer." Students had few comments beyond "education" on the practical applications of Trees(but perhaps we didn't ask the question in the best way).

Teachers mentioned Trees would be very useful in the classroom:

> *Very interesting, helpful for links to click on points of origin (nodes) with details about parrot and T. rex, some of the genetic, developmental [evidence]. A lot of things. Fascinating, if it's done right.*

Another teacher mentioned that these Trees are very important for illustrating evolution vs. creationism. The teachers also mentioned already using such things as dichotomous Trees, similarity indexes and multivariate analyses in the classroom. Teachers said that the Trees relate to prior knowledge about kingdoms (such as in resolving the relationship between animals and fungi).

In Peabody focus groups, there was some uncertainty in the practical applications of Trees of Life. PMNH students commented:

> *It just kinda gives us information, it tells us what we want to know, there's not much you can actually use it for.*
>
> *[Trees are good] for resources, to look something up for a report.*
>
> *[To learn about] evolution, the processes and different time periods of evolution.*

PMNH parents were often as stymied as their children when it came to practical applications. However, there was some interesting discussion regarding the implications for humans or about human impact on the environment:

> *The biodiversity thing because you can see certain branches are more affected, the existing branches might be more at risk or more affected. You can talk about things that might affect creatures in water really do affect creatures on land.*
>
> *Despite all the diversity, there is a common thread, common ancestor, commonality that may make you think twice about doing something destructive. Because like fish, now knowing the relationships and interconnectedness, you may realize what you do to the fish may have potential effects on humans*.

Interest in an Interactive Tree of Life

What would the public be interested in looking up on an interactive Tree of Life when it becomes available? We asked:

- If you could access an interactive Tree of Life on the Internet, what would you want to look up of learn about? What questions do you have?

Interviews

People are interested in learning about a diverse range of things from the Tree of Life, from dinosaurs to the plants in their gardens. Table 1 illustrates the topics interview respondents say they want to learn about.

Table 1

Interview Respondents' interests in an Interactive Tree of Life (N=59)

Topics	Number	%
Topics about Evolution:	30	51
Evolutionary relationships	9	15
Human evolution	8	14
Origins	7	12
Speciation	*5*	*8*
Crops, plants	*3*	*5*
Predictions	*2*	*3*
DNA, genetics	*1*	*2*
Specific species, e.g., dinosaurs	20	34
Accessible information, games	7	12
Teach Tree thinking	2	3
Other	2	3
Don't know	1	2

The following comments illustrate respondents' interests in an interactive Tree:

The history of crops in areas, how civilization evolved with natural grains.

To see connections explained for the layman.

Curiosity, why things are not what they appear [evolutionarily].

Plants: I now find it quite interesting to see which [species] are closer.

Human evolution and projected into the future.

Interview respondents and focus group participants were interested in two broad areas—evolution-related questions and exploration of specific species. Regarding evolution, respondents were interested in the origins of species and speciation. In particular, they wanted to investigate evolutionary relationships raised in our interview (dinosaurs/bird, fungi/elephant/plant and the 5 plants).They also wanted to delve into human evolution. The second major area that interested people is acquiring information about specific species, particularly dinosaurs. Many respondents advised that the Trees should provide information that is accessible to the lay audience, both adults and children. Some suggested games as a hook to draw children (and adults).

Conclusions and Recommendations

How to Read A Tree

Our findings suggest some rather important gaps in visitors' approach to the Tree of Life concept. Although many visitors feel familiar with the expression Tree of Life or even with scientific Trees themselves, misconceptions abound about how they are constructed, how they should be read, and how they could be used by science and society.

While Tree #2 was deemed easiest to understand by the vast majority of interview respondents and focus group participants, it is apparent that any museum presentation of a Tree of Life would benefit from easy-to-read labels, explanations and interpretive keys. Based on this visitor study, we suggest that the Trees used in the exhibition *not* be allowed to speak for themselves. Visitors clearly need guidance as to the significance of the species represented and the relationships between species. Also, it is apparent that visitors want and need clarification of what the nodes or branching points signify and the implication (if any) of the branch lengths. Interpretation must also clarify what Trees can and cannot impart regarding evolutionary time. To dissuade visitors from their assumptions about evolutionary progress (reading left to right, simple to complex or non-human to human), it may be worth clearly explaining how to read a Tree. For example, tell visitors why the species arrayed at the top of the branches have been chosen for the tree and why they are placed where they are. It would also be good to emphasize that trees and evolutionary timelines are two different concepts, and that humans are not at the center or pinnacle of evolution.

AMNH Institute participants, both teachers and students, agreed that labeling the nodes would be helpful. They agreed that making the Tree more complex might mitigate people's bewilderment about Trees. Over-simplification actually may have made the Trees more confusing, not easier to understand.

In focus groups and interviews, respondents overwhelmingly suggested that the trees presented in the exhibition be clearly labeled and explained:

> *I think I'd like it more if they showed the dates of where things split apart and at what point it changed along the line. Like the shark wasn't the same for that entire period of time, I'm sure. So labels showing you where it changed. Also with humans, showing you the different points of the early humans. So instead of showing what they have in common, showing how they evolved from what.*

Most PMNH parents want time represented on the Tree image:

> *Couldn't you layer this with a timeline within the group? If you want to know more about fish, this is the timeline of how they evolved. If you want to know more about mammals, this is the timeline of how they evolved.*

Again and again, respondents asked for more information about the scientific Trees they were wrestling with, a positive indication of potential visitor interest and desire to learn. (A few PMNH parents also suggest including cultural information from mythology or folklore on the Trees of Life, indicating just how thirsty they were for more background and insight.)

Why Read a Tree

It would be valuable to inspire in visitors a sense of awe at the overwhelming interconnectedness of life. It came to our attention that visitors do not grasp the tremendous size and dynamism of the Tree of Life. It would benefit visitors to know that in addition to the small-scale Trees that include only a sampling of species, there is a larger Tree of (All) Life—nearly impossible to graphically represent or comprehend—that comprises innumerable living and extinct species and is always changing.

It would also be valuable to inspire in visitors a sense of awe in the scientific adventure that is tree-building. It is quite surprising how few practical applications of scientific Trees visitors are aware of or can imagine. A few people mentioned "medicines to cure cancer" or "diseases" in general. That only appears to scratch the surface, however. It seems imperative to educate visitors about the Tree's potential for understanding and combating very real emerging diseases like SARS, avian flu, West Nile virus, Ebola and their vectors. Similarly, the value Trees have to conservation—using Trees to avert species extinction, for example—is an area that is sure to capture the public's imagination. Overall, while the economic and practical applications of Tree thinking are readily apparent to scientists, they don't seem to enter visitors' minds very much at all.

One suggestion emerged from all sample groups that might address both "how to read a tree" and "why read a tree." Respondents frequently suggested that the exhibition feature an interactive game that allows visitors to construct their own cladograms or hypothetical species based on a set of evidence (whether their own or scientists').

PMNH campers suggest, for example:

> *Make a game on the Internet where you try to match up things that are related; in the game, when you get it right or wrong, put "you are correct because…"*
>
> *You might learn something you didn't know.*

PMNH parents also suggested including games and touch-screens with more information. They suggest:

> *If there was a picture of a fish, you could touch a screen and get a picture of where it lives, what are its closest relatives, how it relates to us. People want to know "Where do I fit into all of this?" So like find similarities to fish and human DNA.*
>
> *Do the choice thing like you did to us: here is a mammal, who is it more closely related to? Which things are most interconnected? And then have information after that.*
>
> *Or if our understanding has changed, if they used to classify mammals as being on the same branch on the Tree and now if they no longer do, what caused them to change their minds?*

An interactive game would provide an accessible way to help people understand what Trees are, how they are constructed and the various uses they can be put to, both practical and esoteric. It would appeal to visitors to be stimulated, actively engaged and able to access layers of information.

In Closing

A museum exhibition has the potential to capture the public's imagination in a way that a textbook or scientific journal could not. This study shows that people want to know why a mushroom is more closely related to an elephant than to a plant. They want to know the histories of and relationships between themselves, the plants in their gardens and the provocative species that occupy distant lands and times. A Tree of Life exhibition could be the very place to answer these questions. Visitor interest in Trees is very high; in the right exhibition context, visitor understanding could be equally as high.

Finally, we strongly recommend formative evaluation of prototypes once the appropriate Trees are developed for the exhibition. Even though major areas of misunderstanding were uncovered in this front-end study, because this material is so fraught with potential for misinterpretation, testing visitors' response to prototypes can avoid possible miscommunication. We have found that both the language of Tree thinking and the images of Trees do not resonate intuitively with the lay museum-goer. Getting the interpretation right in this exhibition will be challenging but crucial if it is to achieve its learning objectives and have the maximum impact on its audience.

Appendix 1: Data Collection Instruments

Tree of Life Interview **Location:** **Date:**

Excuse me. We are working on a project and would like to ask you a few questions to help us understand visitors' views. It will take about 10 minutes.

Definition

2. When you hear the expression "Tree of Life," what comes to mind?

   (At PMNH: Please sketch your idea of the Tree of Life)

3. *If not mentioned:* Have you heard the term used in science (or biology)? __Yes __No

   [Show image of ToL: shark—T. rex image]

4. This is an example of a scientific Tree of Life. What would you say it's supposed to show people?

5. [*If not mentioned:* Does the tree suggest anything about relationships between species? __Yes __No *If yes,* What does it suggest?

6. What is the significance of each node or branching point?

7. Is the Tree of Life finished? Or is it still growing? [*probe: Is our knowledge of the ToL complete?*]

   [Show 2 other tree images]

8. Here are some different ways scientists have depicted the ToL. Which tree do you find easier to understand? Why?

Species Relatedness[show pictures of organisms]

9. *For each one:* Which of these species would be more closely related in the Tree of Life? Why?

[show cladogram] Does this change what you think? Why?

[bird, caiman, dinosaur]

[fungi, animals, plants]

[pine: magnolia: carnation : tomato, sunflower]

Application

10. What are some ways scientists and society could use this knowledge? [*probe*]

11. How do scientists figure out how thing are related? What kind of evidence would have given rise to this tree?

12. If you could access an interactive Tree of Life on the WWW, what would you want to look up or learn about? What questions do you have?

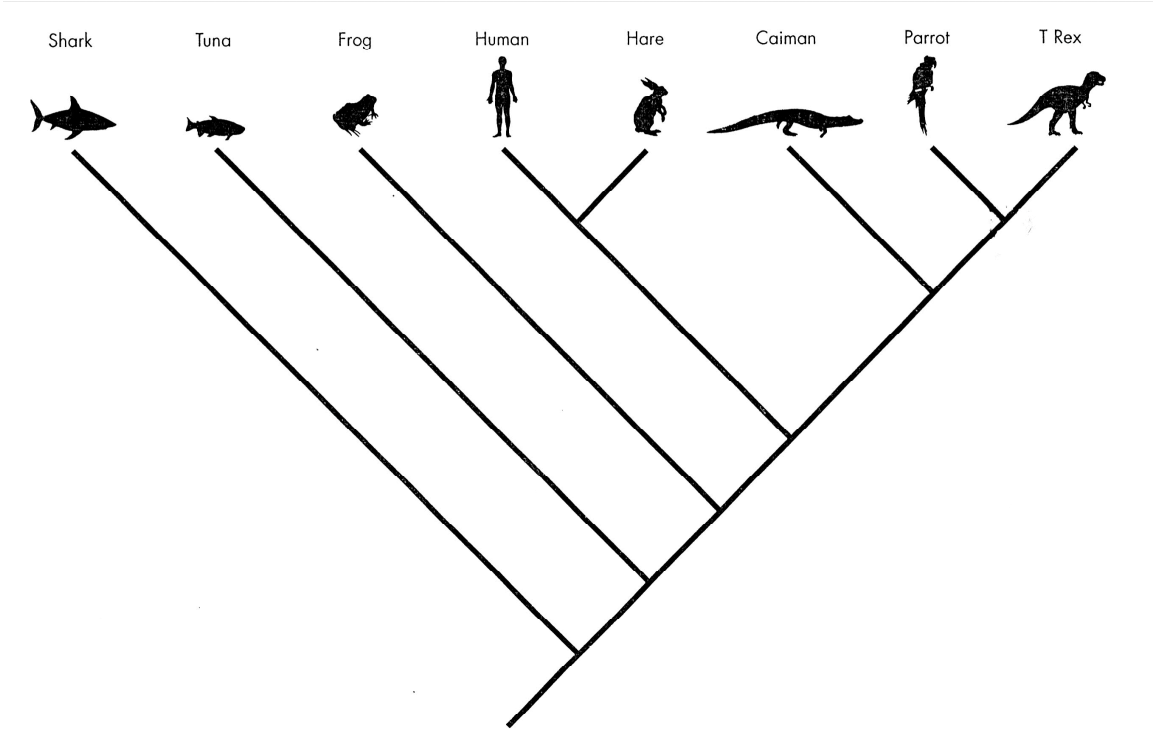
Some information about you:

__ Male	Your Residence:	Your age:	Education…
__ Female	__ NYC	__ 11-19	__In School grade:
Computer use	__ NYC Suburbs	__ 20-39	__ HS grad
__ Daily/Almost daily	__ Other USA	__ 40-59	__College grad
__ Occasionally	__ International	__ 60 and over	__Advanced degree
__ Rarely	Zip code:		
Do you have special training in Science? __No __Yes Please specify:			

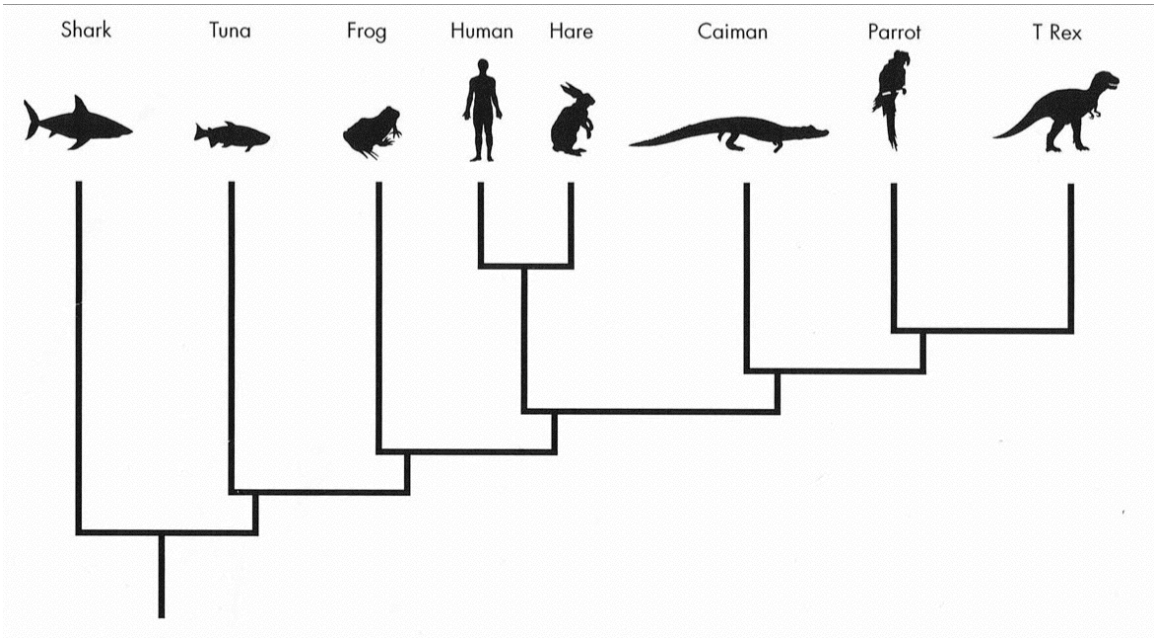
Thank you very much for your time and ideas!

Appendix 2: Trees

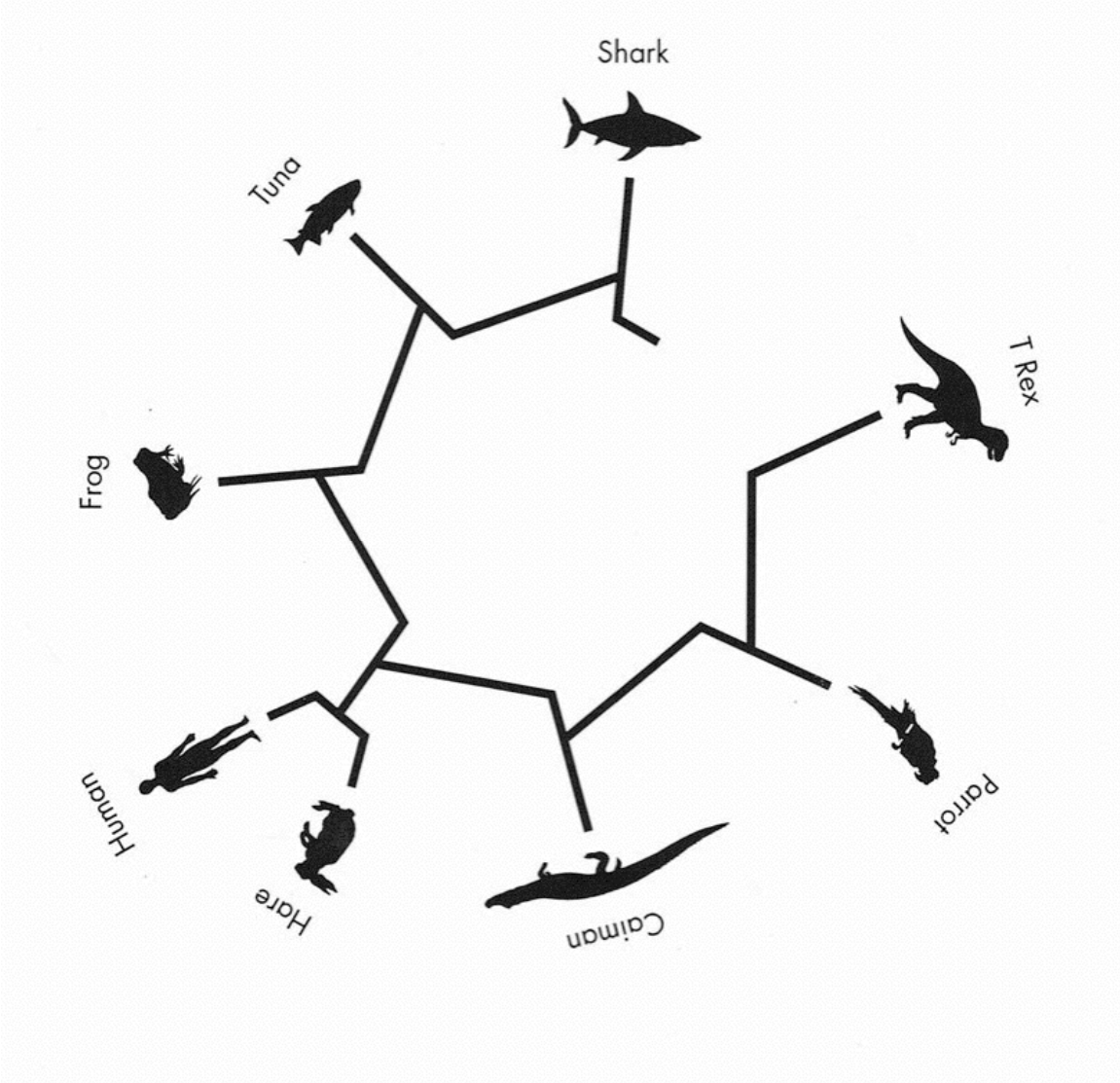
Tree #1



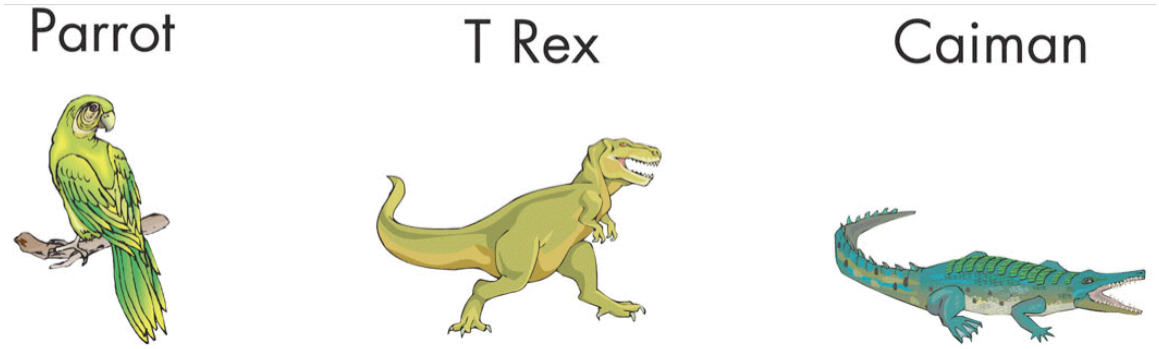
Tree #2

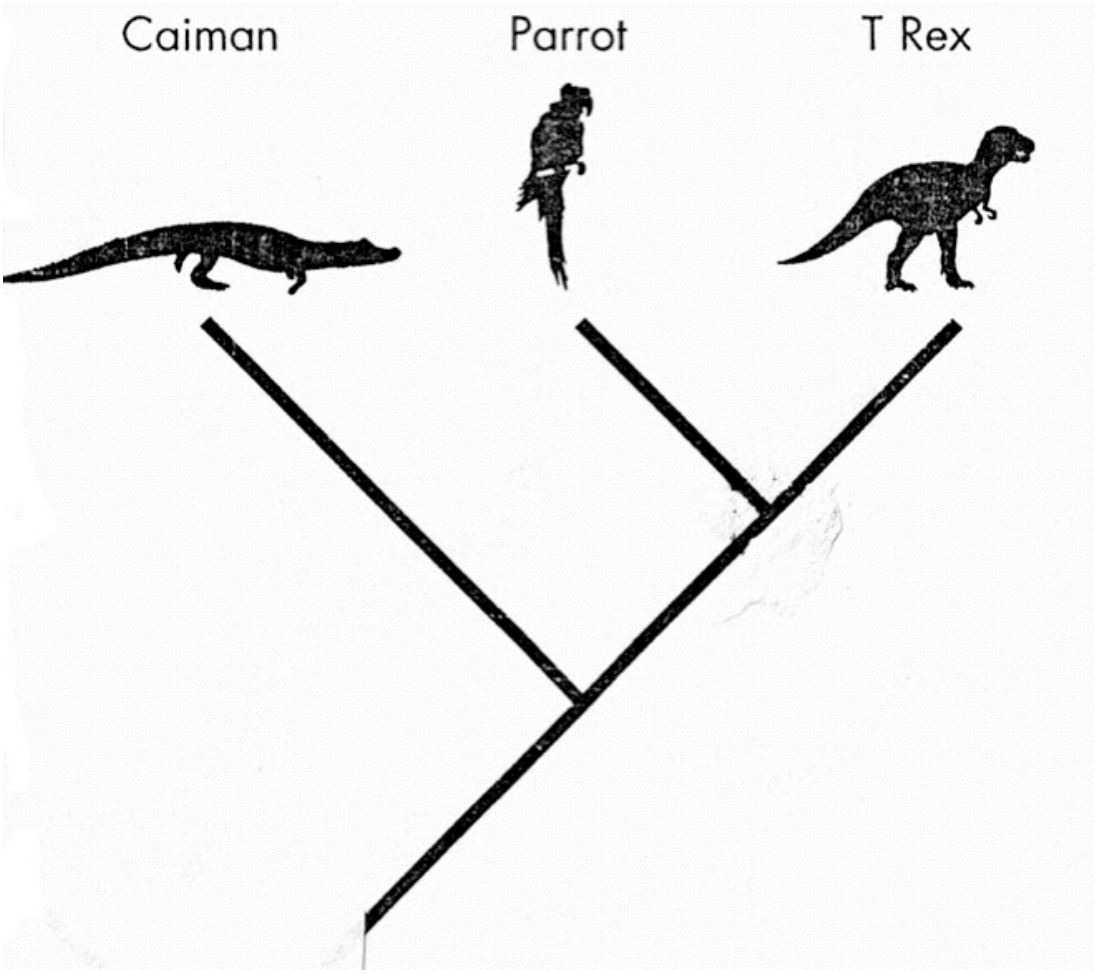


Tree #3

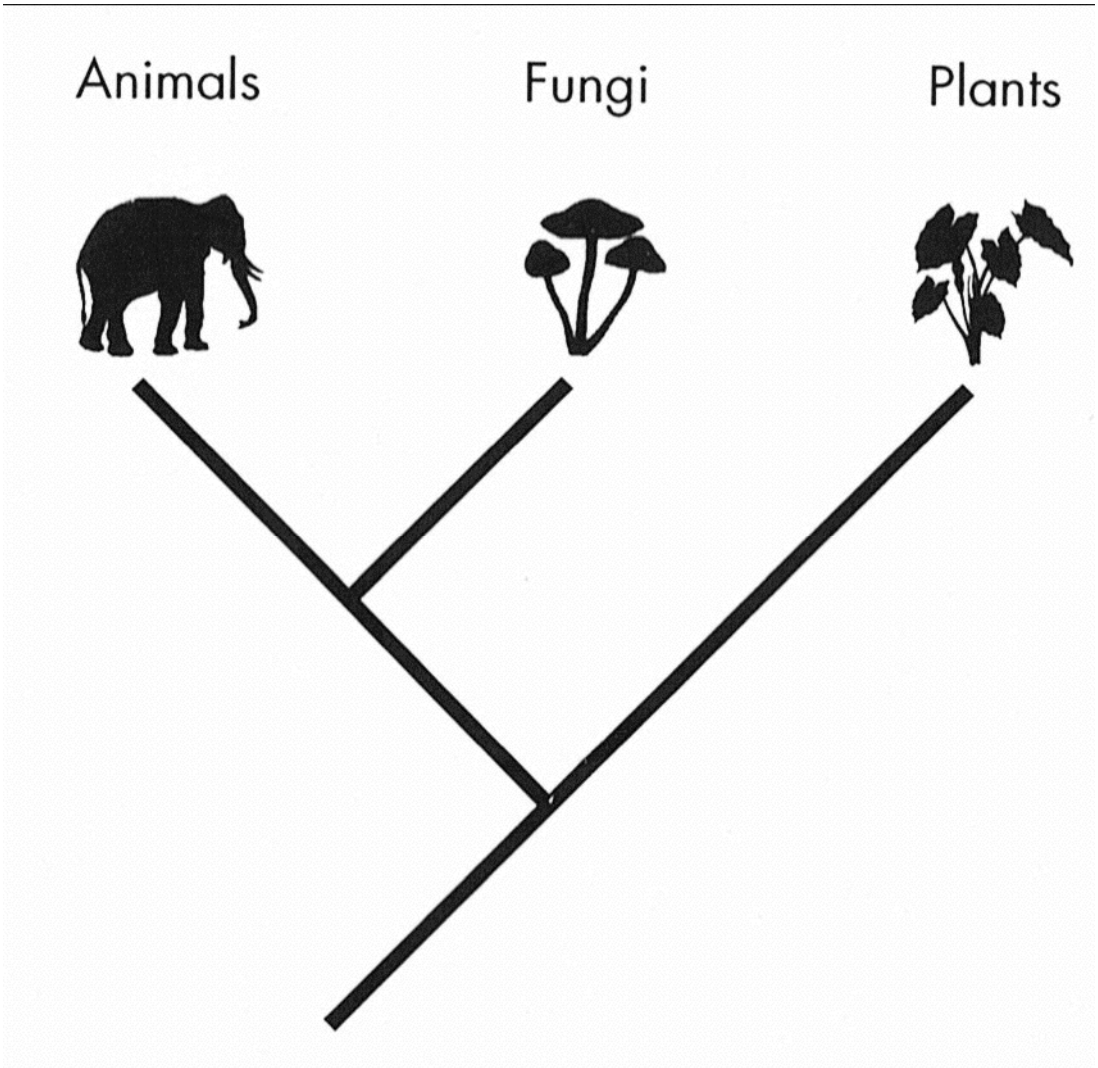


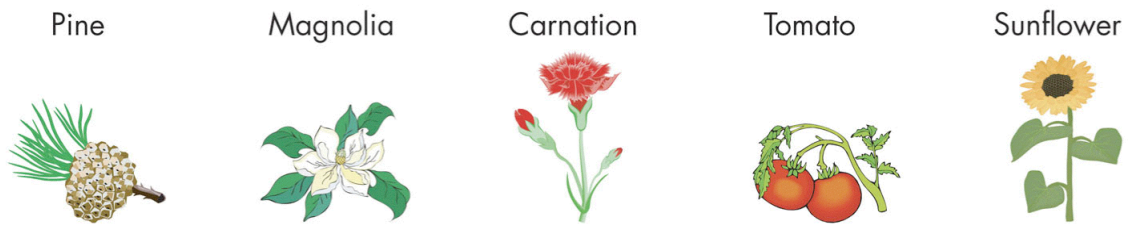
Appendix 3: Species Images: Closely Related Pairs

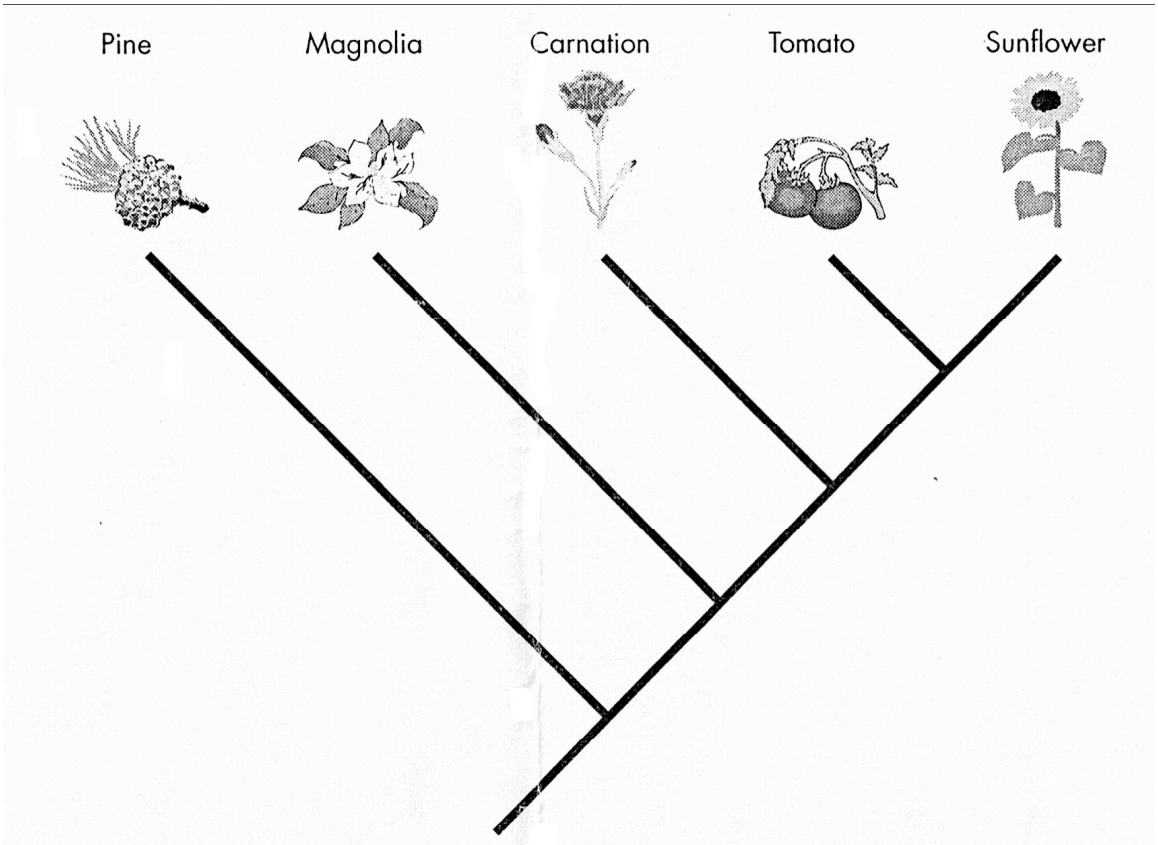





Animals
Fungi
Plants


Animals
Fungi
Plants


Pine
Magnolia
Carnation
Tomato
Sunflower


Pine
Magnolia
Carnation
Tomato
Sunflower

Appendix 4: Demographic Data

Interview Sample

Sex

	Number (N=59)	Percent
Male	30	51
Female	29	49

Computer use

	Number (N=59)	Percent
Daily	54	92%
Occasionally	3	5%
Rarely	2	3%

Residence

	Number (N=59)	Percent*
NYC	17	29%
NYC Suburbs	17	29%
Other USA	18	31%
International	7	12%

*Percents add up to >100 due to rounding

Age

	Number (N=59)	Percent
11to 19	8	14%
20 to 39	32	54%
40 to 59	16	27%
60 and over	3	5%

Education

	Number (N=59)	Percent*
In school	7	12%
HS Grad	7	12%
College Grad	34	58%
Advanced degree	11	19%

*Percents add up to >100 due to rounding

14 respondents (24%) self report special training in science, e.g., math/physics, medical assistant, chemical engineer, history of science teacher, computer science, pre-med student, medicine, biology teacher/researcher.

Focus Group Samples

PMNH
Detailed demographic information was not collected for adult and youth participants in the Peabody Museum focus groups. The parent group consisted of 7 females, aged approximately 30-45 years. The camper group consisted of youths, aged 11-14 years.

AMNH Institute
Formal demographic information was not collected for the teacher and student participants of the AMNH Tree of Life Institute. The teacher sample consisted of 5 adults, 3 females and 2 males, aged approximately 25-35 years. The student sample consisted of 5 teenagers, aged 16-18 years.