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OTHER MEDIA REVIEW

Paleontology and Evolution in the News

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Abstract A review of recent media publications and journal articles about evolution and paleontology

Keywords Hominins · Savannas · African savannas · Grasslands environment · Origin and evolution of oldest life · Earliest life · Yeast · Pregnant plesiosaur · Oldest mammals with placenta · How many species on earth · South Africa · Malapa Caves · New fossils of *Australopithecus sediba*

Review

Savannas and Early Humans

By measuring certain chemical isotopes in ancient soil, Thure Cerling, University of Utah, the senior author of a study to determine the amount of prehistoric tree cover, found that grassy, tree line-dotted savannas prevailed at most East African sites where human ancestors and their ape relatives evolved during the past six million years. A press release from the University of Utah, August 3, 2011, summarizes their work (http://unews.utah.edu/news_releases/6-million-years-of-savanna). By determining how many trees there were, they have "been able to quantify how much shade was available in the geological past…And it shows that there have been open habitats for all of the last six million years in the environments in eastern Africa where some of the most significant early human fossils were found." For students unfamiliar with this environment, a photograph of an East African savanna landscape, a tree-dotted grassland (in Kenya's Samburu National Reserve) is included. Thure Cerling says that "Wherever we find human ancestors, we find evidence for open habitats similar to savannas—much more open and savanna-like than forested…Even 4.3-million-year-old *Ardipithecus*—which lived in the woods, according to its discoverers—had a small component of tropical grasses in its diet." In the past, the definition of a savannah varied considerably, but in this study, Cerling and his colleagues were able to quantify the amount of canopy cover, the basis for deciding if an environment was a savanna. The technique they used to determine tree cover in ancient soils was to determine carbon isotopes in 3,000 modern soil samples and correlate them with satellite photos of tree and vegetation cover at 75 tropical sites worldwide—half in Africa—representing everything from closed forest to open grassland. It turns out that the ratio of rare carbon-13 (C3 plants) to common carbon-12 (C4 plants) in decayed plant material in soils reveals the extent to which the landscape was covered. Trees, shrubs, herbs and cool-season grasses are C3 plants, while C4 plants are warm-season or tropical grasses. "… Analysis of 1,300 fossil soil samples from sites at or near where human ancestors and their relatives evolved show that more than 70% of the sites had less than 40% woody cover…Less than 1% of the samples reflected sites where tree cover exceeded 70%." The research paper was published in *Nature* by Thure E. Cerling and others, volume 476, issue 7358, pages 51–56 "Woody cover and hominin environments in the past 6 million years" (http://www.nature.com/nature/journal/v476/n7358/full/nature10306.html). Some aspects of the study are summarized in the discussion section of the paper: The evolution of early hominins within African

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savannahs has been a core principle of the savannah hypothesis proposed by Raymond Dart to explain the origin of the first Pliocene hominin found in Africa. Since then, debate has evolved from an initial, simplistic "habitat specific" savannah hypothesis, through more sophisticated notions of co-evolution of hominins and their environment, to more recent total rejection of the savannahs as a causal mechanism for the divergence. Using the long-standing recognition that tropical savannahs are predominantly mixed tree–grass systems, the stable isotope evidence from palaeosols discussed in this paper shows that tropical savannahs have been present in East African hominin sites for at least six million years; within the range of savannah environments, the open grassland savannah is much less abundantly represented than the wooded grassland savannah. Thus, within the broadly defined savannah biome, variation in woody cover may have been significant for hominin morphological and behavioral adaptations. Of the several illustrations in the paper, Figure 6 should be useful for teachers and students. It shows a composite record of palaeosol stable isotope composition from the Awash Valley, Ethiopia on the one-hand correlated with one from Omo-Turkana Basin, Kenya and Ethiopia on the other, and between the two is a hominin phylogram where various genera are placed in chorological position.

The preceding paper, as well as the three that follow, were mentioned in various science blogs but did not get much attention in the print media. However, the following three are included here because they are somewhat interrelated and make important contribution to our understanding of early life.

Initial Multicellular Cooperation and Yeast

On August 9, 2011 the following press release was published by EurekAlert (http://www.eurekalert.org/pub_releases/2011-08/plos-ith080311.php) describing the work by John H. Koschwanez, Kevin R. Foster, Andrew W. Murray. This new study has created an analog of what researchers think the first multicellular cooperation might have looked like, showing that yeast cells—in an environment that requires them to work for their food—grow and reproduce better in multicellular clumps than singly. They found that cells of brewer's yeast that clumped together were able more effectively to manipulate and absorb sugars in their environment than were similar cells that lived singly. The experiments showed that in environments where the yeast's sugar food source is dilute and the number of cells is small, the ability to clump together allowed cells that otherwise would have remained hungry and static to grow and divide. The work, published on August 9 in the online, open access journal PLoS Biology, used the yeast *Saccharomyces cerevisiae*, which is commonly used in brewing and breadmaking and has long been used by scientists as a model organism for understanding single-celled life. The researchers devised a series of experiments that presented two problems for the yeast cells to solve if they were to take in enough food to grow and divide: the first was how to change their food from an unusable form to a usable form; the second was how to actually take in this food. The researchers put the yeast in a solution of sucrose—plain old table sugar—which is composed of two simpler sugars, glucose and fructose. Yeast lives on sugar, but the sucrose can't get through the membrane that surrounds the cell. So the yeast makes an enzyme called invertase to chop the sucrose into glucose and fructose, each of which can enter the cell using gate-keeping molecules, called transporters, that form part of the membrane. They said their work offers one explanation as to why single-celled organisms might have initially banded together deep in the history of life, although it's impossible to prove conclusively that this is what happened. "Because there is an advantage to sticking together under these circumstances, and because we know that lots of single-celled organisms make enzymes to liberate goods from their environment, this may be the evolutionary force that led to multicellularity," Murray said. Although, he continued, "short of inventing time travel and going back several billion years to see if this is how it happened…this is going to remain speculation." Here is the citation for the article: John H. Koschwanez, Kevin R. Foster, Andrew W. Murray. Sucrose Utilization in Budding Yeast as a Model for the Origin of Undifferentiated Multicellularity, PLoS Biology, 2011; 9 (8): e1001122 (DOI: 10.1371/journal.pbio.1001122). Included here are the authors' summary of their paper: "The evolution of multicellularity is one of the major steps in the history of life and has occurred many times independently. Despite this, we do not understand how and why single-celled organisms first joined together to form multicellular clumps of cells. Here, we show that clumps of cells can cooperate, using secreted enzymes, to collect food from the environment. In nature, the budding yeast *S. cerevisiae* grows as multicellular clumps and secretes invertase, an enzyme that breaks down sucrose into smaller sugars (glucose and fructose) that cells can import. We genetically manipulate both clumping and secretion to show that multicellular clumps of cells can grow when sucrose is scarce, whereas single cells cannot. In addition, we find that clumps of cells have an advantage when competing against "cheating" cells that import sugars but do not make invertase. Since the evolution of secreted enzymes predates the origin of multicellularity, we argue that the social benefits conferred by secreted enzymes were the driving force for the evolution of cell clumps that were the first, primitive form of multicellular life."

A Scenerio for the Origin of Life

On August 9, 2011, a press release offered from the University of California, Merced described the work of Jason Hein and others (http://www.ucmerced.edu/news/study-builds-plausible-scenario-origin-life-earth) about "Study Builds On Plausible Scenario for Origin of Life On earth" He and his team say that a relatively simple combination of naturally occurring sugars and amino acids offers a plausible route to the building blocks of life. They also say that the precursors of RNA could have formed on Earth before any life existed. Biological molecules, such as RNA and proteins, can exist in either a natural or unnatural form, call enantiomers. By studying the chemical reactions carefully, the research team found it was possible to generate only the natural form of the necessary RNA precursors by including amino acids. Hein said the "These amino acids changed how the reactions work and allowed only the naturally occurring RNA precursors to be generated in a stable form. In the end we showed that an amazingly simple result emerged from some very complex and interconnected chemistry." The study was published in *Nature Chemistry*, volume 3, pages 704–706 (DOI: 10.1038/NCHEM.1108), by Jason E. Hein, Eric Tse, and Donna G. Blackmond, "A route to enantiopure RNA precursors from nearly racemic starting materials."

Yeast and Early Oxygen Production

Several days later on August 16, 2011, another paper appeared discussing the role of yeast, this time in early production of oxygen. Today, oxygen takes up a hefty portion of Earth's atmosphere: Life-sustaining O_2 molecules make up 21% of the air we breathe. However, very early in Earth's history, O_2 was a rare—if not completely absent—player in the turbulent mix of primordial gases. Jennifer Chu wrote the following press release on August 16, 2011, "Breathing New Life Into Earth: Evidence of Early Oxygen in the Oceans of Our Planet" (http://web.mit.edu/newsoffice/2011/early-oxygen-0816.html), a press release from the Massachusetts Institute of Technology (MIT) for an article published the *Proceedings of the National Academy of Sciences*. She writes that it wasn't until the "Great Oxidation Event", nearly 2.3 billion years ago, when oxygen made any measurable dent in the atmosphere, stimulating the evolution of air-breathing organisms and, ultimately, complex life as we know it today. Now, new research from MIT suggests O_2 may have been made on Earth hundreds of millions of years before its debut in the atmosphere, keeping a low profile in "oxygen oases" in the oceans. In laboratory experiments, former MIT graduate student Jacob Waldbauer, working with Professor of Geobiology Roger Summons and Dianne Newman, formerly of MIT's Department of Biology and now at the California Institute of Technology, found that yeast—an organism that can survive with or without oxygen—is able to produce key oxygen-dependent compounds, even with only minuscule puffs of the gas. The findings suggest that early ancestors of yeast could have been similarly resourceful, working with whatever small amounts of O_2 may have been circulating in the oceans before the gas was detectable in the atmosphere. "The time at which oxygen became an integral factor in cellular metabolism was a pivotal point in Earth history," Summons says. "The fact that you could have oxygen-dependent biosynthesis very early on in the Earth's history has significant implications." Waldbauer and colleagues suggest that perhaps O_2 was in fact present on Earth 300 million years before it spiked in the atmosphere—just at extremely low concentrations that wouldn't have left much of a trace in the rock record. To test their theory, they looked to modern yeast as a model. Yeast naturally uses O_2, in combination with sugars, to synthesize ergosterol, its primary sterol. Yeast can also grow without O_2, so long as a source of ergosterol is provided. To find the lowest level of O_2 yeast can consume, the team set up an experiment to identify the point at which yeast switches from anaerobic to aerobic activity. Waldbauer and Summons surmise that oxygen production and consumption may have occurred in the oceans for hundreds of millions of years before the atmosphere saw even a trace of the gas. They say that in all likelihood, cyanobacteria, blue-green algae living at the ocean surface, evolved the ability to produce O_2 via sunlight in a process known as oxygenic photosynthesis. But instead of building up in the oceans and then seeping into the atmosphere, O_2 may have been rapidly consumed by early aerobic organisms. Large oceanic and atmospheric sinks, such as iron and sulfide, spewing out of subsea volcanoes, likely consumed whatever O_2 was left over. "We know all kinds of biology happens without any O_2 at all," says Waldbauer, now a postdoc at Caltech. "But it's quite possible there was a vigorous cycle of O_2 happening in some places, and other places it might have been completely absent." The paper was published on August 16, 2011: J. R. Waldbauer, D. K. Newman and R. E. Summons, Microaerobic steroid biosynthesis and the molecular fossil record of Archean life, *Proceedings of the National Academy of Sciences*, 2011, volume 108, number 33, pages 13409–13414 (DOI: 10.1073/pnas.1104160108). Here is what the authors have to say in the abstract of their paper: The power of molecular oxygen to drive many crucial biogeochemical processes, from cellular respiration to rock weathering, makes reconstructing the history of its production and accumulation a first-order question for understanding Earth's evolution. Among the various geochemical proxies for the presence of O_2 in the environment, molecular fossils offer a unique record of O_2 where it was first produced and consumed by biology: in sunlit aquatic habitats. As steroid biosynthesis requires molecular oxygen, fossil steranes have been used to draw inferences about aerobiosis in the early Precambrian. However, better quantitative constraints on the O_2 requirement of this biochemistry would clarify the implications of these molecular fossils for environmental conditions at the time of their production. Here we demonstrate that steroid biosynthesis is a microaerobic process, enabled by dissolved O_2 concentrations in the nanomolar range. We present evidence that microaerobic marine environments (where steroid biosynthesis was possible) could have been widespread and persistent for long periods of time prior to the earliest geologic and isotopic evidence for atmospheric O_2. In the late Archean, molecular oxygen likely cycled as a biogenic trace gas, much as compounds such as dimethylsulfide do today.

Oldest Fossils on Earth

Unlike the previous items, Google (www.google.com) reports that 260 news outlets and blogs ran the story about the oldest fossils found on Earth. An example of the worldwide reporting is found in the online version of the *New Zealand Herald* (http://www.nzherald.co.nz/the-changing-world/news/article.cfm?c_id=1502962&objectid=10746890) on August 23, 2011 titled "Oldest fossil unearthed in Outback." It reports that the oldest known life forms on Earth have been discovered in samples of rock collected near a remote watering hole in the middle of the Australian Outback. David Wacey of the University of Western Australia says that the fossils are primitive bacteria and lived more than 3.4 billion years ago. The primitive microbes used sulfur instead of oxygen to generate energy from food and "they may be the closest science will ever get to the mysterious origin of life on Earth." The fossils were found in sediment formed in shallow seas, and this find extends the record of life in shoreline or beach environments by 200 million years. He also says "this suggest that beaches could have been the setting for the origin of life itself." The numerous articles that reported the story is based on the following press release from the University of Oxford on August 22, 2011, "Discovered: the oldest fossils on earth" (http://www.ox.ac.uk/media/news_stories/2011/110822.html). The Earth's oldest fossils have been found in Australia by a team from the University of Western Australia and Oxford University. The microscopic fossils show convincing evidence for cells and bacteria living in an oxygen-free world over 3.4 billion years ago. The team, led by Dr David Wacey of the University of Western Australia and including Professor Martin Brasier of Oxford University, report the finding in the journal *Nature Geoscience* (http://www.nature.com/ngeo/journal/vaop/ncurrent/abs/ngeo1238.html) published online on August 21, 2011. "At last we have good solid evidence for life over 3.4 billion years ago. It confirms there were bacteria at this time, living without oxygen," says Professor Brasier of the Department of Earth Sciences at Oxford. The Earth was still a hot, violent place at this time, with volcanic activity dominating the early Earth. The sky was cloudy and gray, keeping the heat in, despite the sun being weaker than today. The water temperature of the oceans was much higher at 40–50°C—the temperature of a hot bath—and circulating currents were very strong. Any land masses were small, or about the size of Caribbean islands, and the tidal range was huge. Significantly, there was very little oxygen present, as there were no plants or algae yet to photosynthesise and produce oxygen. The new evidence points to early life being sulfur-based, living off and metabolizing compounds containing sulfur rather than oxygen for energy and growth. The microfossils were found in a remote part of Western Australia called Strelley Pool. They are very well preserved between the quartz sand grains of the oldest beach or shoreline known on Earth, in some of the oldest sedimentary rocks that can be found anywhere. "We can be very sure about the age, as the rocks were formed between two volcanic successions that narrow the possible age down to a few tens of millions of years," says Professor Brasier. "That's very accurate indeed when the rocks are 3.4 billion years old." The microfossils satisfy three crucial tests that the forms seen in the rocks are biological and have not occurred through some mineralization process: The fossils are very clearly preserved, showing precise cell-like structures all of a similar size. They look like well-known but much newer microfossils from two billion years ago and are not odd or strained in shape. The fossils suggest biological-like behavior; the cells are clustered in groups, are only present in appropriate habitats and are found attached to sand grains. And crucially, they show biological metabolisms. The chemical makeup of the tiny fossilized structures is right, and crystals of pyrite (fool's gold) associated with the microfossils are very likely to be by-products of the sulfur metabolism of these ancient cells and bacteria. At last we have good solid evidence for life over 3.4 billion years ago. The press release contains a few images of the fossils as well as a photograph of the locality. The paper is more extensively illustrated.

Pregnant Plesiosaur

On August 11, 2011, a reporter from the *Daily Mail* wrote about a pregnant sea monster that died 78 million years ago during the Cretaceous period in what is now Kansas (although the article in error locates it in Kentucky). Published in *Mail Online*, (http://www.dailymail.co.uk/sciencetech/article-2025139/Pregnant-fossil-Ancient-sea-monster-solves-mystery-reptile-parenting.html), "Woah

Mama! Ancient fossil of pregnant 'sea monster' solves 200-year old mystery about reptile parenting," it tells us that the "sea monster" was a plesiosaur and that it was carrying a large fetus. Plesiosaurs were discovered almost 200 years ago, and this was the first time one was discovered that was pregnant. The article quotes Frank O'Keefe, of Marshall University in West Virginia, one of the researchers, who explains why the discovery was so important. "It demonstrates that the plesiosaur gives live birth and did not crawl out on land [to lay eggs]. It puts this 200 year mystery to rest." He also said that it is interesting to see how large the fetus was. The actual species is *Polycotylus latippinus* and was 15.4 ft long with a 5-foot-long fetus. However, it was not ready to be born, and if it went to term it might have grown to 6.5 ft in length. The article also extends the results of this find by saying that it indicates that the marine reptiles gave live births. The article is based on one published in *LiveScience* (http://www.livescience.com/15517-pregnant-plesiosaur-big-live-young.html) on August 11, 2011 by Jennifer Welsh. It contains a large painting of a plesiosaur giving birth as well as a photograph of part of the fetus and a plesiosaur skull. One aspect of this discovery is that there is only one fetus. The article attempts to answer why by explaining that when there is only one child, the maternal investment strategy is called "K-selected life history." One of the factors that influence life history is the environment. If it is stable, a higher investment in a lower number of offsprings pays off, because they are less likely to be lost. "If the environment is undergoing changes, making lots of babies could be a better strategy (so if one dies, there are others to pass on your genes)". "Compared with the Triassic, the Jurassic and the Cretaceous periods had relatively stable environments." Also, the K-selected life history indicates that the plesiosaur may have lived in familial social groups and engaged in extended parenting, similar to modern-day whales and dolphins. This article and many others in the press, blogs and other news outlets are based on the scientific paper published in *Science* on August 12, 2011 (Science, vol.333, 870, DOI: 10.1126/Science.1205689) by F.R Keefe and L.M. Chiappe of Marshall University and the Natural History Museum of Los Angeles County, respectively. The paper contains excellent diagrams of the skeletons. The authors describe their reasoning and evidence for identifying the smaller of the two specimens as a fetus and not just a juvenile individual.

Oldest Mammal with Placenta

The *Pittsburg Post-Gazette* provided on its website, post-gazette.com (http://www.post-gazette.com/pg/11236/1169507-100.stm) an article saying that a "Carnegie team finds fossil of oldest mammal with placenta," published on August 24, 2011. The specimen in question was "discovered in 2009 in northeastern China representing the earliest mammal ever to be discovered that had a placenta, or was in the process of developing a placenta, to nourish its unborn." This discovery in 160-million-year-old Jurassic rocks, extends back in time when mammals developed a placenta. Previously, the oldest placental mammal was found in 125-million-year-old Cretaceous rocks. The authors of the study gave it the name *Juramaia sinensis* because it was found in the Jurassic, and *maia* means mother, in reference to the placenta; and *sinensis*, the country in which it was found. The specimen is now housed in the Beijing Museum of Natural History. The article indicates that the specimen is small, about two inches long, but almost better than seeing it are the excellent illustrations in the scientific article providing clear, much enlarged details of the specimen. The specimen is described as shrew-like and is the earliest known member of eutherians, "the group that evolved to include all mammals that have a placenta to nourish their unborn offspring….The fossil features an incomplete skull, skeletal parts and, remarkably, impressions of residual soft tissues such as hair." The species provides evidence of when eutherian mammals diverged from other mammals, namely, the metatherians whose descendants include marsupials including kangaroos, and monotremes such as the platypus. Media interest was widespread because *J. sinensis* was an example of the earliest of its type, here is an example of one of the articles, "Fossil redefines mammalhistory", published in BBC News Science & Environment (http://www.bbc.co.uk/news/science-environment-14651218) on August 25, 2011 by Jonathan Amos. He begins the article with "A small, 160-million year-old-Chinese fossil has something big to say about the emergence of mammals on earth." The specimen comes from Liaoning Province where so many outstanding fossils have been discovered, a few of which have been mentioned previously in this column. Besides the skull, forearm and wrist bones, the fossil includes remains of a full set of teeth and forepaw bones, which have enabled the paleontologists to place the animal among the eutherians. Also contained in the article is a drawing of what the animal may have looked like. The scientific paper was published in *Nature* (http://www.nature.com/nature/journal/v476/n7361/full/nature10291.html) on August 25, 2011, in volume 476, pages 442–445, "A Jurassic eutherian mammal and divergence of marsupials and placentals" by Zhe-Xi Luo, Chong-Xi Yuan, Qing-Jin Meng & Qiang Ji. The paper contains illustrations of the specimens, restoration of the partly preserved skeleton and skull and the dental feature including jaw and teeth. Included is a chart showing basal eutherian and metatherian phylogeny. Today, placentals are the most abundant mammals, and have diversified into every niche for vertebrates, and have dominated the world's terrestrial biotas since the beginning of the Cenozoic.

How Many Species Are There?

Carl Zimmer, writing in the *New York Times*, “How Many Species? A Study Says 8.7 Million, but It’s Tricky,” on August 23, 2011 (http://www.nytimes.com) says that each year, researchers report more than 15,000 new species. “Ask any taxonomist in a museum, and they’ll tell you they have hundreds of species waiting to be described,” says Camillo Mora, a marine ecologist at the University of Hawaii. The article reports that scientists have named and cataloged 1.3 million species. “How many more species there are left to discover is a question that has challenged taxonomists for two centuries.” Boris Worm, a marine biologist at Dalhousie University in Nova Scotia and Dr. Mora and their colleagues published a paper in the journal *PLoS Biology* in which they “estimate that there are 8.7 million species on the planet, plus or minus 1.3 million.” Not only were there over 750 articles published in various media outlets in the first few day of its release (www.google.com), but the article has also been drawing strong reactions from other experts. “In my opinion this is a very important paper,” said Angela Brandt, a marine biologist at the University of Hamburg in Germany. “But critics say that the method in the new paper can’t work, and that Earth’s true diversity is far greater. However, other estimates have ranged from as few as three million to as many as 100 million. The article presents various views of other scientists discussing the validity of the method used to derive the number of species. David Pollock, an evolutionary biologist at the University of Colorado says that “this appears to be an incredibly ill-founded approach.” There are 43,271 cataloged species of fungi, the basis for which Dr. Mora and his colleagues estimate that there are 660,000 species of fungi on Earth. But other studies on fungus diversity suggest the number may be as high as 5.1 million. Two days after the Zimmer article, the *New York Times* published the following on its editorial page: “How Many Leaves on the Tree of Life?” “In 1691, the scientist John Ray estimated that there were 20,000 species of insects. His numbers were significantly off—at least a million insect species have been described so far...Three centuries later, there is no scientific consensus on the total number of species…According to the study, it would take another 1,200 years to provide a scientific description of them all at our current pace…It doesn’t include the species of bacteria, which may number in the millions. It is the bare truth to say that no matter how much we think we know about life on Earth, we know almost nothing.” As usual the news stories are based on a press release, this one rather long, seven pages, including illustrations (www.eoearth.org/files/news-release-how-many-species-on-earth.pdf). The article is published in *PLoS Biology*, volume 9, number 8, 7 pages@ (e1001127 DOI: 101371/journal.pbio.1001127), “How Many species Are There on Earth and in the Ocean?” by Camilo Mora, Derek P. Tittensor, Sina Adt, Alistair G.B Simpson and Boris Worm. The press release tells us the new estimated total number of species on Earth—the most precise calculation ever offered—is 6.5 million species found on land and 2.2 million (about 25% of the total) dwelling in the ocean depths. Announced by Census of Marine Life scientists, the figure is based on an innovative, validated analytical technique that dramatically narrows the range of previous estimates. Until now, the number of species on Earth was said to fall somewhere between 3 and 100 million. Furthermore, the study says a staggering 86% of all species on land and 91% of those in the seas have yet to be discovered, described and cataloged. Says lead author Camilo Mora of the University of Hawaii and Dalhousie University in Halifax, Canada: "The question of how many species exist has intrigued scientists for centuries and the answer, coupled with research by others into species' distribution and abundance, is particularly important now because a host of human activities and influences are accelerating the rate of extinctions. Many species may vanish before we even know of their existence, of their unique niche and function in ecosystems, and of their potential contribution to improved human well-being.” Dr. Worm notes that the recently updated Red List issued by the International Union for the Conservation of Nature assessed 59,508 species, of which 19,625 are classified as threatened. This means the IUCN Red List, the most sophisticated ongoing study of its kind, monitors less than 1% of world species. Drs. Mora and Worm, together with Dalhousie colleagues Derek P. Tittensor, Sina Adl and Alastair G.B. Simpson, refined the estimated species total to 8.7 million by identifying numerical patterns within the taxonomic classification system (which groups forms of life in a pyramid-like hierarchy, ranked upwards from species to genus, family, order, class, phylum, kingdom and domain). Analyzing the taxonomic clustering of the 1.2 million species today in the Catalogue of Life and the World Register of Marine Species, the researchers discovered reliable numerical relationships between the more complete higher taxonomic levels and the species level. Says Dr. Adl: "We discovered that, using numbers from the higher taxonomic groups, we can predict the number of species. The approach accurately predicted the number of species in several well-studied groups such as mammals, fishes and birds, providing confidence in the method." When applied to all five known eukaryote kingdoms of life on Earth, the approach predicted:

1. ~7.77 million species of animals (of which 953,434 have been described and cataloged)
2. ~298,000 species of plants (of which 215,644 have been described and cataloged)

3. ~611,000 species of fungi (molds, mushrooms; of which 43,271 have been described and cataloged)
4. ~36,400 species of protozoa (single-cell organisms with animal-like behavior, eg. movement, of which 8,118 have been described and cataloged)
5. ~27,500 species of chromista (including, e.g., brown algae, diatoms, water molds, of which 13,033 have been described and cataloged)

Total: 8.74 million eukaryote species on Earth. "Awaiting our discovery are a half million fungi and moulds whose relatives gave humanity bread and cheese," says Jesse Ausubel, Vice-President of the Alfred P. Sloan Foundation and co-founder of the Census of Marine Life. "For species discovery, the 21st century may be a fungal century!" Mr. Ausubel notes the enigma of why so much diversity exists, saying the answer may lie in the notion that nature fills every niche, and that rare species are poised to benefit from a change of conditions. In his analysis, Lord May says the practical benefits of taxonomic discovery are many, citing the development in the 1970s of a new strain of rice based on a cross between conventional species and one discovered in the wild. The result: 30% more grain yield, followed by efforts ever since to protect all wild varieties of rice, "which obviously can only be done if we have the appropriate taxonomic knowledge." "Given the looming problems of feeding a still-growing world population, the potential benefits of ramping up such exploration are clear," Concludes Dr. Mora: "With the clock of extinction now ticking faster for many species, I believe speeding the inventory of Earth's species merits high scientific and societal priority. Renewed interest in further exploration and taxonomy could allow us to fully answer this most basic question: What lives on Earth?" Students and teachers should take the opportunity to view the materials in the research paper as well as the website Census of Marine Life (http://www.coml.org), which contains a wealth of information as well as illustrations of marine life.

More On Human Evolution

As I was completing this issue's column the *Wall Street Journal* published an extensive article on human evolution, "Fossil Treasure Trove Sheds Light on a stage of evolution" (http://online.wsj.com/article/SB10001424053111903285704576558382651436242.html) by Robert Lee Hotz. He reports that scientists in South Africa have discovered a hoard of fossil finds "documenting a puzzling forerunner to modern mankind that lived two million years ago, with human-like hands and ape-like feet." Although the newspaper edition contains a black and white illustration showing the features of the fossil, *Australopithecus sediba*, the online version is in color and includes an additional illustration of its skull; a photograph of Professor Lee Berger, the discoverer of the specimens, holding its cranium; a cranium of the juvenile skeleton, and a reconstructed skull. The fossils were found in the Malapa Cave at the United Nations Cradle of Humankind World Heritage Site, about 28 miles from Johannesburg, South Africa. So far, 220 bones from five individuals, including infant, juvenile, and adult remains representing both sexes have been found. "From head to toe, the bones reveal an unexpected patchwork of primitive and advanced traits." It has a tiny skull, long arms, and diminutive body which are all chimp-like, but the hands, ankles, and pelvis were surprisingly modern. "Based on its analysis, the international research team of 80 scientists and technicians, led by Lee Berger of the University of Witwatersrand in Johannesburg, said the species was the most probable ancestor of the family to which modern human beings belong, the genus *Homo*." Dr. Berger indicated that the specimens represent a model that could lead to the genus *Homo*, but as the field of paleoanthropology is contentious, a number of researchers disagreed and indicated that they though the species was an evolutionary dead end. "They dated the finds at 1.977 million years old, based on a lab estimate of the rate of decay of uranium traces in the cave sediments." Included in the article is a chart listing a decade of discoveries related to human evolution starting with 2001 when three previously unknown prehuman species were discovered in Africa, dating back almost six million years; in 2003, the oldest known fossils of modern humans, *Homo sapiens*, were found in Africa, dating back 160,000 years; in 2006, the remains of a 42-million-year-old prehuman species, *Australopithecus anamensis*, were found in an area of Ethiopia, where seven other human-like species also once lived; in 2008, the first fossil of *Australopithicus sediba*, dating back almost two million years, was found by a nine-year-old boy; in 2009, a 4.4 million-year-old skeleton of an early human ancestor called *Ardipithecus namida* was unveiled after a decade of study; and in 2010, the oldest fossil evidence of modern humans in eastern Asia was found, dating back at least 100,000 years. Within a few hours of the publication of this story the *Wall Street Journal* received more than 150 responses and comments, the array of opinions ranging from awe to derogatory comments, and from acceptance of the basic conclusions to near-ridicule. Five research reports were published in the *Science*, September 9, 2011 (www.sciencemag.org) which includes an image of the right forearm and hand on its cover. The issue also includes a video reconstruction of the fossil's skull and an audio interview with Lee Berger. A summary text is available as well on EurekAlert (http://www.eurekalert.org/pub_releases/2011-09/aaft-sp090211.php), which includes an image of the right hand of the adult female fossil superimposed on a modern human hand. In addition to the rich material provided in *Science*, Ann Gibbons, in *Science*'s NEWSFOCUS, (www.sciencemag.org) has an article, "Skeletons Present an Exquisite Paleo-Puzzle," (pages 370–372), where she writes that "Partial skeletons of 2-million-yesar-old hominin *A. sediba* leaves researchers impressed by their completeness but scratching their heads over the implications for our family tree." The value of the article is twofold: it briefly reviews the discoveries of hominins in Africa and interviews a number of researchers who have studied these fossils, as well as others. Here they present their brief opinions about what the skeletal features show and how they relate to others. What is surprising is that there are a number of skeletons that have been excavated at various sites but have not been described formally such as the "still mysterious, extraordinarily complete, and largely unpublished skeleton dubbed "Little Foot" from Sterkfontein." The lead researcher, Lee Berger, found the first specimen at Malapa in 2008 and subsequently found a partial skull and skeleton of a boy who was about 12–13 years old and a second partial skeleton of an older female. Berger suggests that they fell into a hidden pit, perhaps seeking water that had percolated up from an underground cave. After the initial find, the cave collapsed and the site is now an open pit yielding the remains of at least two other individuals, including an infant whose bones have not been analyzed. The 1.997 million year old date of *A. sebida* places it in the "murky" period just after the rise of *Homo*, and the demise of *Australopithecus africanus*. The endocast has "the best resolution ever found on African hominin…" Others agree. "The pictures of this thing are beyond belief," says Ralph Holloway, a neuropaleontologist at Columbia University. "I've never seen anything so stunningly, graphically clear…Berger has put the new hominin in with the australopithecines rather than as an early member of *Homo*. But he points out that the new skeletons share several key traits with *Homo* that are not found in Lucy's species, citing the precision grip and the reorganization of the brain." At this time, it seems that no one is reorganizing the family tree. Paleoanthropologist Carol Ward of the University of Missouri "says that whatever you call these things, there seem to be a number of different species running around at the same time—a number of experiments in being hominin."