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Athabasca Glacier, Jasper National Park, Alberta, Canada, showing recession since 1935. Courtesy Marli Bryant Miller, www.marlimillerphoto.com

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ARTICLE

Pleistocene Continental Glaciers: A Single Ice Age Following a Genesis Flood or Multiple Ice Ages?

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Introduction

Young-earth creationist Larry Vardiman (1993, 2009) has proposed that the continental glaciation that occurred during the Pleistocene Epoch in North America, Greenland, northern Europe, and northern Asia (Figure 1) was a single ice-age event that occurred following the Genesis worldwide Flood, about 4500 years ago or about 2500 BCE, and postulates that the

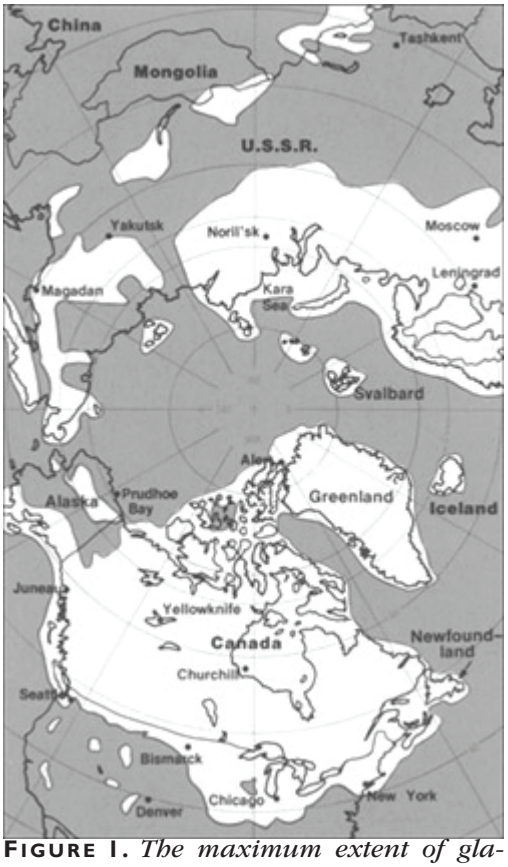

Figure 1. *The maximum extent of glacial ice in the north polar area during Pleistocene time. (Map from the United States Geological Service, http://pubs.usgs.gov/gip/continents/.)*

earth is about 6000 years old based on Bishop Ussher's estimate (Ussher 1786). Another creationist estimate (Osgood 1981) suggests that the Flood occurred in 2304 BCE, but Vardiman's choice of 2500 BCE is more common and will be used here.

In his model, Vardiman, like Snelling (2007, 2009), asserts that the Ice Age was caused by volcanic eruptions along mid-ocean ridges during catastrophic plate tectonics—an idea promoted by Baumgardner (2002, 2003). The model proposes that these eruptions heated the ocean waters so that huge amounts of water vapor were released into the upper atmosphere to provide the source of the water that produced the great thicknesses of continental ice.

Snelling (2009) indicates that water temperatures in the oceans were raised to levels 20°C warmer than today. The heated water is alleged to have formed "hypercanes" (enormous hurricanes) that rapidly precipitated the snow to form the polar ice sheets in just 500–600 years (Vardiman 2009). Oard (1990, 2004, 2005) calculated that the Ice Age lasted about 700 years and ended "within the last several millennia." Because these authors did not indicate a time for melting of the ice, we must conclude that the extension of the ice into the United States from Canada and the subsequent melting occurred soon after this time period and that *the* single Ice Age ended about 2000 BCE. Oard (1997) also dismissed all pre-Pleistocene glacial deposits as resulting from submarine landslides during the Noachian Flood (Heaton 2009).

Vardiman (1993) and Oard (2005) studied the data in published reports describing the annual layers in the Greenland ice cap in a core at Camp Century, Greenland. Uniformitarian models, using oscillations of delta ^{18}O values, indicate that the deposition of snow formed this ice cap during the last 110 000 to 125 000 years (Johnsen and others 1972; Meese and others 1997). Vardiman (1993), however, suggests that these annual layers could actually have been deposited in just 500 years and that the delta ^{18}O values can be better interpreted as giving ages in the last 4500 years. He believes that various factors cause the conventional interpretations of annual layers to be in error because the delta ^{18}O values can be affected by several influences, such as proximity of the ice layers to the ocean, acidification by volcanic ash and gases, temperature changes between storms, plasticity and flowage that thins the ice layers, and melting to produce firnication (converting snowflakes to ice by melting and re-freezing), although he concedes that the interpretation of the existence of recent annual layers is accurate through a limited range.

Oard (1990, 2004) agrees with Vardiman that the uniformitarian model (accepted by almost all geologists today) for the origin of the Pleistocene continental glaciation is not correct. He suggests, however, that instead of catastrophic plate tectonics that produced volcanic eruptions in mid-oceans to produce the heat that warmed the ocean waters, it was the "fountains of the great deep" that burst open to supply the warm water.

> In the six hundredth year of Noah's life, in the second month, on the seventeenth day of the month, on that day all the fountains of the great deep burst forth, and the windows of the heavens were opened. And rain fell upon the earth forty days and forty nights. (Genesis 7:11–12, RSV)

Oard (1990:6) points out:

> The earth's crust warms about 10°F per 1000 feet (2°C per 100 m) depth. If the water for the fountains came from 3000 feet (900 m), it would be quite warm. If it came from 10 000 or more feet (3000 m), the water would have been hot.

Therefore, in Oard's model, this hot water was added to the water that came from rain that fell during the 40 days and 40 nights of the Noachian Flood, and the warmed water would supply copious quantities of vapor that would have precipitated as the large volumes of snow that produced the one-time continental Ice Age. He combines this "fountains-of-the-deep" model with abundant volcanism in wide parts of the world during the Pleistocene Epoch to produce huge amounts of ash and gas that were trapped in the stratosphere. This ash and gas would act as an "anti-greenhouse":

> instead of warming the earth, it would reflect sunlight back into space and cool it. At the same time, infrared radiation would continue to escape the earth. (Oard 1990:3).

He suggests that this cooling by both processes is what caused the water vapor to precipitate as snow in the north polar regions to produce the Pleistocene one-time Ice Age.

Figure 2. *Generalized geographic map of North America in Pleistocene time. (Map from the United States Geological Service, http://pubs.usgs.gov/gip/continents/.)*

Glaciation during the Pleistocene Epoch

Vardiman (1993) points out that the farthest advance of the Pleistocene continental glaciers was nearly to the southern end of Illinois (Figure 2), but claims that this advance represents the maximum extent of the ice mass during a one-time Ice Age event that supposedly lasted only 500–600 years. According to the uniformitarian model, 500–600 years would represent only the last part of the Wisconsinan stage, the youngest stage of the Pleistocene

Epoch, which may have lasted nearly 57 000 years (Table 1). Although Vardiman (1993) and Oard (1990, 2004, 2005) indicate "fluctuation" or "surges" of a single ice mass, Snelling (2009), on the other hand, claims that there was only one ice advance and only one retreating ice sheet, and that there never were interglacial periods.

TABLE 1. *Holocene and Glacial and Interglacial Stages of the Pleistocene Epoch*

	Dating (thousands of years before present)	Duration (thousands of years)
Holocene	0–10	10
Wisconsinan	10–67	57
Sangamon	67–128	61
Illinoian	128–180	52
Yarmouthian	180–230	50
Kansan	230–300	70
Aftonian	300–330	30
Nebraskan	330–470	140

Adapted from Gleason and Stone (1994:153, table 7.1). Glacial stages are in **boldface***; interglacial stages are italicized.*

Nevertheless, all these authors seem to ignore the evidence for interglacial times and older Kansan and Nebraskan stages (Table 1; Dutch 1997; Stanley 2009; Wicander and Monroe 2010). Note that the older Kansan and Nebraskan stages listed on Table 1 are no longer valid names. Because of more complicated pre-Illinoian glaciation of the central United States, other names are now substituted, such as the Independence stage (Richmond and Fullerton 1986; GAGE 2000). But these name changes and calling such older glacial stages as "pre-Illinoian" give a better understanding of the glacial history.

If all four formerly accepted glacial stages of Table 1 (or so-called "fluctuations" in Vardiman's model) were in a single Ice Age event, then all the various glacial tills deposited in that single event should have approximately the same age and have the same amount of time available for soils to form on top of them by weathering processes.

The amount of time since the end of Vardiman's "one-time Ice Age event" is estimated to be 4011 years. That is, if the Noachian Flood is alleged to have occurred in 2500 BCE and if the Ice Age lasted 500 years, the end of the Ice Age would be 2500 minus 500 or 2000 BCE. From that end-time until the present year of CE 2011 is 4011 years for soil formation to occur.

SOILS FORMED DURING THE PLEISTOCENE EPOCH

According to the conventional geologic model, the youngest glacial ice cap is Wisconsinan in age, and its terminal moraine (the moraine that records the farthest advance of the glacier) is about 230 km south of Chicago in the middle part of Illinois. The farthest advance of all the continental glaciers from Canada south into the United States was during the Illinoian stage, and its terminal moraine is near the southern tip of Illinois, near Carbondale,

465 km south of Chicago (Figure 2). Soils that occur on the ground moraines of both Wisconsinan and Illinoian age have formed from the loess that overlies each of these moraines. (The origin of this loess is discussed in the next section.)

There are numerous soil types in Illinois, but mollisols and alfisols are the dominant types (USDA nd; Barnhardt 2010). Mollisols occur in 45 percent of the state's land area in northern Illinois on loess lying above Wisconsinan glacial till. Alfisols occur in 45 percent of the state's land area in southern Illinois on loess on top of Illinoian glacial till.

Soil formation is a very slow process. Older soils have deeper and thicker subsoil horizons if other soil producing factors remain constant. The alfisols in southern Illinois have a thick soil profile and support a mixed conifer and deciduous forest. They have been deeply weathered in the following way: (1) the feldspar grains in the loess have been extensively converted to clay in a thick soil profile, (2) iron-bearing minerals have been oxidized to form red hematite (iron oxide) and yellowish brown limonite (hydrated iron oxide), and (3) calcium in calcium carbonate cement and other elements have been leached out for depths of several decimeters. As a result, the alfisols in southern Illinois are light brown.

In contrast, in northern Illinois the mollisols are black and were originally covered by prairie grasses whose roots decomposed to make the soil rich in black organic matter (USDA nd). The mollisols exhibit a less thick soil profile in which (1) the feldspars in the loess are not as extensively converted to clay to the same depth as in the alfisols, (2) the iron-bearing minerals are not as oxidized to form hematite and limonite, and (3) little leaching of calcium and other soluble elements occurs. The alfisols in southern Illinois are not nearly as productive for agriculture as are the mollisols (USDA nd). Farmers living in Illinois north of the Wisconsinan terminal moraine enjoy rich farmland and do not have to add lime to their black mollisols, whereas farmers living south of the Wisconsinan terminal moraine have to add lime and other fertilizers to their brown alfisols to replenish the missing leached elements.

These differences in the color and the characteristics of the mollisols and alfisols show an important relationship that Vardiman (2009), Snelling (2009), and Oard (1990, 2004, 2005) have not considered in their models; nor have they any explanation for them. Various factors determine the soil type, including topography (rolling hills or flat plains), vegetation (forest or grasses), climate (temperature and precipitation), and time (USDA nd). Given that the distance between these two soil types is a kilometer or less and they exist on terrain at essentially the same elevation, separated only by the Wisconsinan terminal moraine, how could these soils have been formed and modified simultaneously after a single Ice Age event at about 2000 BC? Because the black mollisols to the north and the brown alfisols to the south differ across this short distance and the climate is the same for both areas, some other factors must have produced the differences. Vardiman's, Snelling's, and Oard's models do not explain why. Oard (1990) dismisses the evidence for soils forming on loess during interglacial stages because he believes that correlations of horizons in soil profiles and rates of deposition of loess are not dependable. Nevertheless, different soils exist, and rates of deposition and horizon correlations are not the deciding factors as to whether interglacial stages occurred.

Glacial till of the Illinoian stage and its overlying weathered brown alfisols can be traced north under the younger Wisconsinan glacial till and its black mollisols for several hundred kilometers (Table 1; Dubsky and others 2000; Soller and others 1999; Kolata and Nimz 2010; McKay and others 2008; Hansel and others 1999). Because the Illinoian till and its weathered alfisols are buried under the Wisconsinan till and its mollisols, the Wisconsinan terminal moraine cannot be a recessional moraine of the same Illinoian glacier that nearly reached the southern tip of Illinois.

Not only did multiple glaciations cause the distribution of soils of different ages to vary, but they also caused topography to vary. When there has been more time for erosion, streams will have cut down into the soil and underlying rock and created rolling hills, typical of southern Illinois (USDA nd). Northern Illinois, on the other hand, has nearly flat topography, indicating that little time for erosion has been available following the disappearance of the last glacial ice cover. In other words, the difference in topography also supports the supposition that the alfisols in the south and mollisols in the north are not the same age—as would be expected if these soils had formed nearly simultaneously on loess of the same age during a one-time Ice Age as proposed by Vardiman (1993, 2009), Snelling (2009), and Oard (1990, 2004, 2005).

Loess formation during the Pleistocene Epoch

Another feature of continental glaciation that has been totally ignored by Vardiman (1993, 2009), Snelling (2009), and Oard (1990, 2004, 2005) is the occurrence of loess (wind-blown ground-up rock called "glacial flour") on which the mollisols and alfisols were formed. Each of the four continental ice caps in Canada (or the one-time ice cap of Snelling 2009) was probably 2400–3000 meters thick (Anonymous 2011) in order for them to flow by gravity as far south as the middle and southern tip of Illinois (Figure 2). When these ice caps began to melt back, becoming less thick and decreasing their widths, huge amounts of flood waters drained off the surface area of the ice, eroded through the bordering moraines, and transported large quantities of glacial flour downstream. Much of this powdered rock would have been deposited as silt in river flood plains, in some places as much as 100–300 kilometers wide, and these flood plains would have extended across western United States south of the Canadian border. (This width is logical but has not been documented in the literature. However, it is commonly accepted knowledge.)

During winters when little to no meltwater was coming from the ice cap, these flood plains would dry out, allowing the silts (finely powdered quartz and feldspar crystals) to be converted into dust. Then, cold winter winds coming from the northwest and blowing across the flood plains would pick up this dust and transport it eastward in huge dust storms. In this way, the exposed glacial tills in Iowa, Illinois, Indiana, and Ohio became covered with this dust, known as loess. Loess layers, as much as 70 meters thick, were deposited in the Loess Hills of Iowa and Missouri along the eastern side of the Missouri River valley (USGS 1999; Prior and Quade nd). East of the Illinois River valley in Illinois the loess is 7–10 meters thick (personal observation), and then progressively farther east, the loess deposits diminish in thickness to less than a decimeter in Ohio.

Because each glacial stage allowed thick loess to be deposited on top of the older Illinoian and pre-Illinoian (Kansan and Nebraskan) glacial tills, each of these loess deposits becomes evidence for younger interglacial stages. This means that former ice caps covering

Canada had to melt back at least three previous times to expose these glacial tills so that the loess could be deposited on top of each of them. This cyclic, repeated, extensive melting in the midst of a supposed one-time Ice Age alternating with vast volumes of snow precipitated in very cold climates cannot logically happen in 500–700 years. That is, the models proposed by Vardiman (1993, 2009), Snelling (2009), and Oard (1990, 2004, 2005) do not provide a climatic mechanism to cause such rapid melting or ablation of large volumes of ice in a cold Ice Age in such a short time during the Sangamonian, Yarmouthian, and Aftonian interglacial stages (Table 1). Moreover, the statement by Snelling (2009) that there "never were interglacial periods" is completely negated by the occurrence of loess deposits on tops of the glacial tills. Although Oard (2005) argues that a succession of atmospheric carbon dioxide and methane contents of the ice in the Vostok ice core in Antarctica give evidence for a single Ice Age, Petit and others (1999) argue that these data indicate four glacial-interglacial cycles during 420 000 years.

Qualifying statements

Actually, Vardiman (2009), Snelling (2009), and Oard (1990, 2004, 2005) do not specify when the end of the one-time Ice Age occurred although they suggest that it lasted 500–700 years. Since these authors consider that the ice caps on Greenland and Antarctica were rapidly deposited, they presumably would concur that these ice caps are remnants of their one-time Ice Age. According to these young-earth proponents, these ice caps would remain because both are surrounded by polar oceans that supply moisture that falls as annual snow during winters and because less snow melts during the summers than has fallen during the winters. Nevertheless, because Snelling argues that the average thickness of the ice sheet on the North American continent was only 700 meters (and presumably did not have a maximum thickness of 2400–3000 meters as estimated by glaciologists (Anonymous 2011), most of the ice in his explanation must have been gone in recent history because of rapid melting. However, if the end of the ice coverage in North America is not 500–700 years following the Flood at 2500 BCE or 4011 years ago but at some younger time, this would leave even less time in Vardiman's, Snelling's, and Oard's models for the deposition of loess on the tops of the glacial tills. And this would further limit the development of soils on this loess and the erosion of the glacial-till-covered landscapes to produce rolling hills in southern Illinois.

^{14}C-isotopic dating

According to Vardiman (2009), the Ice Age followed on the heels of the worldwide Noachian Flood dated at approximately 2500 BCE. One must then question the actual timing and validity of the global Flood envisioned by young-earth proponents (Senter 2011). ^{14}C-isotopic dating, although questioned by young-earth creationists, has produced results that verify the accuracy of the ^{14}C-dating method. For example, the ^{14}C-date of plant fragments found in plaster in King Hezekiah's Siloam tunnel is the same as that recorded in biblical records to be 2711 years ago or 700 BCE (2 Kings 20:20; Rogerson and Davies 1996; Bower 2003; Frumkin and others 2003; Deem 2006). This date is consistent with the reign of King Hezekiah from 727 BCE to 698 BCE.

On that basis, ^{14}C-dating of 11 850 years ago is not unreasonable for logs, branches, needles, and pine cones in a spruce, pine, and hemlock forest buried by a glacial moraine that was deposited during a very late advance of the glacier ice cap of Wisconsin age at Two

Creeks, Wisconsin, near the western shore of Lake Michigan (Black 1974). This date of 11 850 years ago is much older than 2000 BCE that is estimated for the models of Vardiman, Snelling, and Oard for the end of the 500–700-year–long, single Ice Age.

Furthermore, ^{14}C-dating of spruce wood, cones, and needles in a forest buried under loess near Charleston, Illinois, about 58 kilometers north of the Wisconsinan terminal moraine, give dates of about 20 000 years ago (Hansel and others 1999). This forest was growing in and adjacent to a former shallow thermokarst lake (created by thawing of permafrost) on top of Wisconsinan glacial till near Shelbyville, Illinois. This lake is about 600 kilometers south of the above-mentioned buried forest at Two Creeks, Wisconsin, dated at 11 850 years ago. On the basis of the different ages of the two buried forests, there was about 8150 years for the Wisconsinan glacier to retreat (melt back) across this 600 kilometers, and this time, of course, is also longer than the 6000 years favored by Vardiman (1993) for the age of the earth . If the ^{14}C-dating method gives values that are consistent with biblical records, it is logical that the dependable, natural, physical laws, which the Creator made, should also be dependable for ^{14}C-dating applications to older glacial features.

Conclusions

Vardiman (1993, 2009), Snelling (2009), and Oard (1990, 2004, 2005) can omit data to make their models work, but we generally expect that scientific studies include all relevant data in developing a hypothesis. These authors have not done so.

There are no known physical laws that would allow catastrophic movements of 100-km–thick oceanic-basaltic crustal masses across thousands of kilometers, rapid eruptions of great numbers of volcanoes over the entire planet, and subsequent warming of planetary oceans through these processes. The creationists propose that the Ice Age was a single event, lasting 500–700 years with "fluctuations" or "surges" of ice advances during this single event. This model is ingenious but faulty.

The problem with their model is the evidence of three (and possibly more) well-formed (thick) soil profiles on top of each supposed glacial "surge" during the 500–700 years projected in the creationists' model of the Ice Age. Weathering of loess and glacial till to form a soil by hydration and oxidation of silicate minerals is a very slow process in a cold climate—as is quite apparent by observations made in the last 4000 years in northern United States, Canada, Europe, and Asia. The lack of well-developed soils in these northern regions contrasts with thick, well-developed soils formed in hot tropical climates near the equator in Brazil.

The creationists use an accelerated model for the deposition of great amounts of snow and ice in 500–700 years but seem not to realize that this acceleration also requires (1) simultaneous acceleration of melting and ablation of three ice caps that are 2400–3000 meters thick and (2) subsequent acceleration of weathering and soil formation between "surges" during this same short time. Even the alleged 4011 years (but probably more than 11 850 years and as much as 20 000 years) since the end of the melting of the Wisconsinan glacier are not sufficient time to produce a soil profile on loess as thick and well-developed as occurs on the underlying older Illinoian loess, supposedly formed in less than 700 years. Thus Vardiman, Snelling, and Oard have not produced sound scientific models. There is

no valid evidence, claimed by Snelling, that there was only one ice advance and only one retreating ice sheet, and that there never were interglacial periods.

These authors ignore those data that do not support their models: data supporting at least four different ice ages, but perhaps as many as six (Johnson 1986) that occurred within the last 680 000 years. Their models cannot account for (a) the long times necessary to form deeply-weathered, oxidized, brown alfisols in southern Illinois compared to less-weathered and oxidized, black mollisols on younger Wisconsinan glacial till in northern Illinois; (b) the deposition of loess on tops of layers of exposed glacial tills, requiring long periods of melting between continental ice-cap depositions; and (c) age dating by ^{14}C-methods, placing logs, branches, needles, and pine cones in a spruce, pine, and hemlock forest buried in a most recent moraine (Wisconsinan) near Two Creeks, Wisconsin, at 11 850 years ago and for a similar buried forest at Charleston Lake in southern Illinois, dated at 20 000 years ago.

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References

[Anonymous]. 2011 [cited 2011 Mar 24]. Laurentide Ice Sheet. [Internet]. Chicago: Encyclopedia Britannica. Available from: http://www.britannica.com/EBchecked/topic/332438/Laurentide-Ice-Sheet.

Barnhardt ML. 2010. Soils. In: Kolata DC, Nimz CK, editors. *Geology of Illinois.* Champaign (IL): Illinois State Geological Survey. p 373–384.

Baumgardner JR. 2002. Catastrophic plate tectonics: The geophysical context of the Genesis Flood. *TJ* (now *Journal of Creation*) [Internet]. [cited 2011 Mar 15]; 16(1):58–63. Available from: http://www.answersingenesis.org/tj/v16/i1/plate_tectonics.asp.

Baumgardner JR. 2003. Catastrophic plate tectonics: The physics behind the Genesis Flood. In: Ivey Jr RL, editor. *Proceedings of the Fifth International Conference on Creationism*. Pittsburgh (PA): Creation Science Fellowship. p 113–126.

Black RF. 1974. *Geology of the Ice Age National Scientific Reserve of Wisconsin* [Internet]. National Park Service Scientific Monograph Series 2. Washington DC: US Government Printing Office; [cited 2011 Sep 15]. Available from: http://www.cr.nps.gov/history/online_books/science/2/contents.htm.

Bower B. 2003. Ancient tunnel keeps biblical date. *Science News* 164:221.

Deem R. 2006 [cited 2011 May 15]. Hezekiah's Siloam Tunnel confirmed through C-14 dating [Internet]. Available from: http://www.godandscience.org/apologetics/hezekiah.html.

Dubsky J, Hort J, Sleeth B. 2000 [cited 2011 Mar 15]. Glacial drift in Illinois [Internet]. Available from: http://jove.geol.niu.edu/faculty/fischer/429_info/429trips/NIF/Illinois_Glacial_Drift_Map.htm.

Dutch S. 1997 [cited 2011 Mar 16]. Glaciers [Internet]. Green Bay (WI): University of Wisconsin, Green Bay. Available from: http://www.uwgb.edu/dutchs/EarthSC202Notes/glacial.htm.

Frumkin A, Shimron A, Rosenbaum A. 2003. Radiometric dating of the Siloam Tunnel, Jerusalem. *Nature* 425:169–171.

[GAGE]. Work Group on Geospatial Analysis of Glaciated Environments. 2000 [cited 2011 Sep 14]. Pre-Wisconsin glaciation of central North America [Internet]. Emporia (KS): Emporia State University. Available from: http://academic.emporia.edu/aberjame/gage/pre-wisc/pre-wisc.htm.

Gleason PJ, Stone P. 1994. Age, origin, and landscape evolution of the Everglades Peatland. In: Davis S, Ogden J, editors. *Everglades: The Ecosystem and its Restoration*. Boca Raton (FL): St Lucie Press. p 149–198.

Hansel AK, Berg RC, Phillips AC, Gutowski VG. 1999. *Glacial Sediments, Landforms, Paleosols, and a 20 000-year-old Forest Bed in East-Central Illinois*. Illinois State Geological Survey Guidebook 26. Champaign (IL): Illinois Geological Survey.

Heaton TH. 2009. Recent developments in young-earth creationist geology. *Science and Education* 18:1341–1358.

Johnsen SF, Dansgaard W, Clausen HB, Langway CC Jr. 1972. Oxygen isotope profiles through the Antarctic and Greenland ice sheets. *Nature* 235:429–434.

Johnson WH. 1986. Stratigraphy and correlation of the glacial deposits of the Lake Michigan Lobe prior to 14 ka BP. *Quaternary Science Reviews* 5:17–22.

Kolata DR, Nimz CK, editors. 2010. *Geology of Illinois*. Champaign (IL): Illinois State Geological Survey.

McKay ED, Berg RC, Hansel AK, Kemmis TJ, Stumpf AJ. 2008. *Quaternary Deposits and History of the Ancient Mississippi River Valley, North Central Illinois. Fifty-first Midwest Friends of the Pleistocene Field Trip, May 13–15*. Illinois State Geological Survey Guidebook 35. Champaign (IL): Illinois State Geological Survey.

Meese GA, Gow AJ, Alley RB, Zielinski GA, Grootes PM, Ram K, Taylor KC, Mayewski PA, Bolzan JF. 1997. The Greenland Ice Sheet Project 2 depth-age scale: Methods and results. *Journal of Geophysical Research* 102(C12):26,411–26,423.

Oard MJ. 1990. *An Ice Age Caused by the Genesis Flood*. El Cajon (CA): Institute for Creation Research.

Oard MJ. 1997. *Ancient Ice Ages or Gigantic Submarine Landslides?* Creation Research Society Monograph Series 5. Chino Valley (AZ): Creation Research Society Books.

Oard MJ. 2004. *Frozen in Time: The Woolly Mammoth, the Ice Age and the Bible*. Green Forest (AR): Master Books.

Oard MJ. 2005. *The Frozen Record: Examining the Ice Core History of the Greenland and Antarctica Ice Sheets*. El Cajon (CA): Institute for Creation Research.

Osgood J. 1981. The date of Noah's Flood. *Ex Nihilo* (now *Creation*) [Internet]; [cited 2011 Mar 10]; 4(1):10–13. Available from: http://www.answersingenesis.org/articles/cm/v4/n1/date-of-noahs-flood.

Petit JR, Jouzet J, Raynaud D, Barkov NI, Barnola JM, Basile I, Bender M, Chappellaz J, Davis M, Delaygue G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Pépin L, Ritz C, Saltzman E, Stievenard M. 1999. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica. *Nature* 399:429–436.

Prior JC, Quade DJ. [nd] [cited 2011 Mar 15]. The Loess Hills: A geologic view [Internet]. Iowa City [IA]: Iowa Geological and Water Survey, Iowa Department of Natural Resources. Available from: http://www.igsb.uiowa.edu/Browse/loess/loess.htm.

Richmond GM, Fullerton DS. 1986. Summation of Quaternary glaciations in the United States of America. *Quaternary Science Reviews* 5:183–196.

Rogerson R, Davies PR. 1996. Was the Siloam Tunnel built by Hezekiah? *Biblical Archaeologist* 59:138.

Senter P. 2011. The defeat of flood geology by flood geology. *Reports of the National Center for Science Education* 31(4):1.1–1.14.

Snelling AA. 2007 [cited 2011 Mar 15]. Can catastrophic plate tectonics explain flood geology? [Internet]. Petersburg [KY]: Answers in Genesis. Available from: http://www.answersingenesis.org/articles/nab/catastrophic-plate-tectonics.

Snelling AA. 2009. *Earth's Catastrophic Past: Geology, Creation and the Flood*. El Cajon (CA):Institute of Creation Research, vol 2.

Soller DR, Price SD, Kempton JP, Berg RC. 1999. Three-dimensional geologic maps of quaternary sediments in east-central Illinois. US Geological Survey Geologic Investigations Series Map I-2669. Denver (CO): US Geological Survey.

Stanley SM. 2009. *Earth System History*, 3rd ed. New York: WH Freeman and Company.

[USDA] US Department of Agriculture Natural Resources Conservation Service. [nd] [cited 2011 Mar 23]. Soils of Illinois [Internet]. Washington DC: United States Department of Agriculture. Available from: http://www.il.nrcs.usda.gov/technical/soils/soilsofil.html.

[USGS] United States Geological Survey. 1999 [cited 2011 Mar 15]. Geology of the Loess Hills, Iowa [Internet]. Washington DC: US Geological Survey. Available from: http://pubs.usgs.gov/info/loess.

Ussher J. 1786. *The Annals of the World*. London: Printed by E Tyler for J Crook and G Bedell.

Vardiman L. 1993. *Ice Cores and the Age of the Earth*. Santee (CA): Institute for Creation Research.

Vardiman L. 2009. *Wild, Wild Weather—Genesis Flood and the Ice Age* [videodisc; Internet]. Petersburg (KY): Answers in Genesis; [cited 2011 Mar 10]. 1 videodisc: sound, color, 60 min. Available from: http://www.answersingenesis.org/media/video/ondemand/wild-weather/wild-wild-weather.

Wicander R, Monroe JS. 2010. *Historical Geology*, 6th edition. Belmont (CA): Brooks/Cole.

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FEATURE

People and Places: George Rappleyea (1894–1966)

Randy Moore

FIGURE 1. *George Rappleyea (right) instigated the Scopes Trial, the most famous event in the history of the creationism/evolution controversy. Rappleyea is shown here with John Scopes. From the Smithsonian Institute Archives, image #2005-35069.*

George Washington Rappleyea was born on July 4, 1894. After serving in the Corps of Engineers during World War I, he was placed in charge of the six struggling coal and iron mines of the Cumberland Coal and Iron Company (and its 400 employees) just outside of Dayton, Tennessee.

In 1925, the 31-year-old Rappleyea noticed an ad in the May 4 issue of the Chattanooga newspaper placed by the ACLU looking for a teacher to test Tennessee's newly passed Butler Law banning the teaching of human evolution in the state's public schools. Rappleyea went to Robinson's Drug Store, where he showed the ad to FE Robinson (a local druggist and head of the county board of education), Walter White (county superintendent of schools), and other local leaders. The group eventually asked coach and substitute science teacher John Scopes if he would help the community publicize Dayton by being arrested for violating the statute. Scopes agreed, and Rappleyea swore out a warrant against Scopes and wired the ACLU for help. The result was the Scopes trial, the most famous event in the history of the creationism/evolution controversy. Rappleyea—Scopes's original prosecutor and most vocal and visible local supporter—was represented by attorney Sue Hicks, a friend of Scopes. Hicks was later immortalized by Chicago writer Shel Silverstein in "A Boy Named Sue," a song popularized by Johnny Cash's live recording *At San Quentin*.

Rappleyea gave visitors tours of Dayton, spoke with reporters, and remodeled an abandoned 18-room house for the defense lawyers and expert witnesses. That house, located about a mile south of Dayton, was the largest in Rhea County and was known as "The Mansion". (In *Inherit the Wind*, several of the participants in the trial stayed at a fictitious hotel by the same name.) In 1927, Rappleyea attended Scopes's appeal, which resulted in the original conviction's being set aside.

After Scopes's famous trial, Rappleyea returned to his work at Cumberland Coal and Iron Company. On November 29, 1925, *The New York Times* reported that Rappleyea had been ordained a bishop in the Liberal Church of Denver, Colorado, the same position that the church had offered to Scopes during his trial. Unlike Scopes, however, Rappleyea accepted the position and announced that his official title was "Doctor of Liberal Religion". Rappleyea did not establish a branch of the church in Dayton, but he liked having the power to perform weddings and other duties ordinarily performed by the clergy.

Later, Rappleyea and his wife left Dayton for a job in the boating industry in Mobile, Alabama. In January 1937, Rappleyea went to New York and helped form the American Boat Builders and Repairers, and later that year staged a widely-publicized mock battle on and over Long Island Sound between nineteen planes and ten powerboats. In the late 1930s, Rappleyea—then an officer of Higgins Boat Industries in New Orleans—helped charter the United States Power Squadron, and developed equipment to help build landing-strips on beach sand for the Marines. Rappleyea then became a vice president of the American Power Boating Association, and in the following three years wrote several books and pamphlets about boating. In September 1944, Rappleyea patented an improvement in aerial mapping cameras, after which he became treasurer of Marsalis Construction Company in New Orleans. There, on March 2, 1947, Rappleyea was arrested for conspiring to violate the National Firearms Act. On March 31, 1948, Rappleyea pleaded guilty in federal court in Biloxi, Mississippi, to conspiracy to ship arms and ammunition to British Honduras, and on

April 24, 1948, he began serving a 366-day sentence in the Federal Correction Institution at Texarkana, Texas.

After being released from prison, Rappleyea moved to Southport, North Carolina, and resumed his work as a chemical engineer. The September, 1951 issue of *Popular Mechanics* reported that Rappleyea had developed a way to build houses out of molasses (for only $1000 per house), and in 1955 Rappleyea patented Plasmofalt, an asphalt-molasses stucco-like material used to stabilize adobe.

Rappleyea spent his final years in Miami, Florida, where he directed the Tropical Agricultural Research Lab. Rappleyea died on August 29, 1966, and was buried near the entrance of Arlington National Cemetery in Arlington, Virginia.

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FEATURE

Science Denialism: Evolution and Climate Change

David Morrison

Introduction

In spite of the United States' primacy in science and technology, there are two broad areas of science that many of our citizens refuse to accept: biological evolution and global warming. Most advanced countries find this paradox baffling. American rejection of evolutionary science has been frequently studied over more than a century. Our denial of climate science is a much more recent phenomenon, since climate science itself is only a few decades old. There are some interesting common elements in these two cases of science denialism, including the similar tactics used to attack both evolutionary and climate science.

First consider some of the superficial similarities. Opinion polls suggest that the scientific consensus in both evolution and global warming is rejected by many Americans. Denialism in both fields is supported by well-financed campaigns. Both scientific fields also have popular villains, namely Charles Darwin and Al Gore, whose very mention in many circles is sure to generate boos and smirks. Both issues have become increasingly politicized, with the more conservative elements of the Republican Party tending to ally themselves with the denialists (see, for example, Gelbspan 2004 or Mooney 2005).

There is also a tendency in both camps to ignore well-accepted science in favor of idiosyncratic interpretations to "explain away" observations supporting the mainstream (evolution and global warming) positions. Readers of *RNCSE* are familiar with creationist examples of this, but the global warming denialist contentions have not been discussed here. When global warming denialists are not stubbornly claiming that no warming is taking place, they contend that any warming seen is the result of cyclical or historical causes such as the ice ages. This is to cast doubt that human-generated greenhouse gases are important factors in climate change. And yet historical, non-anthropogenic climate cycles have no connection to the changes we are seeing today.

First, of course, today's warming is taking place far faster than any historical cycles. Further, the evidence clearly shows that we are not experiencing changes in the earth's orbit and rotation axis (which are the primary cause of the ice ages) or any changes in solar energy (which are implicated in the "medieval warm period" and the "little ice age"). Both the solar output and the orbit of the earth are monitored with exquisite precision by astronomers, and neither is changing. Most fundamentally, current climate changes carry the unambiguous signature of greenhouse warming: rapid increase in the atmospheric concentration of carbon dioxide and methane, cooling of the stratosphere while the troposphere warms, concentration of warming in polar regions, excess deposition of heat into

the oceans, and imbalance in the energy budget of the planet. Efforts to invoke historical "naturalistic" mechanisms to explain today's climate changes have no more validity than appeals to Lamarckian explanations for evolution.

Evolutionary theory and global warming theory both have strong and weak forms. In evolution the weak form is theistic evolution. This accepts the age of the earth and biological change, including common descent, while still maintaining belief in the Creator who has guided the evolutionary process toward the ultimate goal of humans formed in the image of God. The strong version relies only on natural processes and rejects the idea of a direction or preordained goal for evolution. In global warming the weak version accepts the reality of increasing temperatures, but attributes the current warming to various natural processes, a position which, as mentioned above, lacks scientific support. The strong version recognizes that the current rapid rise in temperature is unique and is caused by human consumption of fossil fuels. In both cases, many more people accept the weak version than the strong one. Scientists, however, prefer the strong versions, because the process of science relies on natural cause-and-effect relationships that can be used to understand the world around us. Efforts of supporters of the weak form of global warming to invoke inapplicable historical mechanisms to explain today's climate changes are as inscrutable and lacking in empirical evidence as efforts by supporters of the weak form of evolution to explain evolution through supernatural interference.

Readers may feel that biological evolution is much more firmly established than global warming, since it has been the foundation for our understanding of the living world for over a century. Global warming, in contrast, is a recent idea in the much smaller field of atmospheric and climate science. Perhaps in this respect the two fields cannot be compared, but I am struck by similarities in the campaigns used against both, which share many common elements of anti-science, populist propaganda.

Using Pseudoscience to Undercut Real Science

Although traditionally the primary opposition to evolution has come from fundamentalist Christians (and recently fundamentalist Muslims as well), it has become fashionable to reframe the issue in secular terms. This strategy has been forced on the evolution denialists by court decisions prohibiting the intrusion of sectarian religious beliefs into the science curriculum. Attempts to require the teaching of creationism or "intelligent design" (ID) in public schools have been rejected by the courts and by most school administrations.

In response to the adverse legal environment, the anti-evolution strategy consists of two parts: (1) insisting that evolution is only one of several possible descriptions of the origins of biological diversity and that fairness requires that we teach alternatives; and (2) asserting that the scientific evidence for evolution is actually weak, with increasing dissent among scientists. To support these positions, the anti-evolution forces try to frame their arguments in scientific terms, to support the claim that creationism (or ID) is a respectable alternative, and that there are many legitimate secular scientific criticisms of biological evolution. Their target, of course, is not to convert the scientific community, but to influence public opinion.

The warming denialists are focused on political policy, not grassroots public support. They must convince decision-makers that the evidence linking climate change to fossil fuel consumption is too weak to justify government regulations or incentives that might change

our energy policies. The only way they can make their case is to deny the international scientific consensus on the causes of climate change. With the support of energy-industry companies and such influential newspapers as the *Wall Street Journal* and the *Washington Times* (see Gelbspan 2004 and Mooney 2005), they insist that the science of global warming is weak and that many of the climate scientists are not only in error, but also actively conspiring to distort the data and suppress dissenting views.

To be successful, both denialist groups must mount what appear to be credible challenges to mainstream science. One strategy is to find a few pliable scientists to do research that undercuts evolution or climate science and publish this research in peer-reviewed scientific journals. The first of the projects or phases in the creationist "wedge strategy" was "scientific research, writing, and publicity," in order to establish the scientific credibility of ID. Performing research that affirmed creationist or ID ideas and getting this research published has proved impossible, but since the target audience does not read the scientific literature, there is an alternative. Because books, lectures, newspaper articles, and websites are not peer-reviewed, denialists can address these objectives through popular-level writing and publicity, and still convince much of the general public that their arguments are scientifically valid.

Tactics to Promote Pseudoscience

A populist strategy used by both groups of denialists is to reject any scientific evidence that is not obvious. In the ID world, this leads to the idea of irreducible complexity. If they (or the general public) cannot understand how natural selection could lead to the flagellum or the eye or the chemical sequence involved in photosynthesis, then they claim that science cannot do so either, and we must accept divine intervention. The warming denialists similarly reject the output of computer models. One often-repeated refrain is that the evidence for warming is based on models and therefore cannot be trusted. Climate models are indeed complex, and they do not always agree on details such as the timing of future warming. However, the evidence for warming is empirical, and its future trends are anchored in basic physics, such as the greenhouse effect and the heat capacity of the oceans.

The most sophisticated climate models generally agree in their predictions for the next twenty years, but predicting the future is not their primary purpose. A numerical model is a scientific research tool for exploring the effects of different assumptions and inputs. (For a general description, see http://en.wikipedia.org/wiki/Global_climate_model.) For example, climate models can help us understand how a major volcanic eruption will affect climate, or what is likely to happen under different CO_2 emission scenarios. Unfortunately, their scientific *strength*—the ability to show how different inputs can produce different results—is touted as a *weakness* by denialists.

Many proponents of creationism and ID have become expert debaters who know how to control both the venue and rules of engagement in their confrontations with scientists. A simple message skillfully crafted and presented to a sympathetic audience will generally defeat a scientist trying to discuss nuanced and complex issues in front of a hostile crowd. Such tactics keep the creationist base activated, even if they do not convert the scientific community.

The warming denialists likewise avoid big scientific meetings and prestigious journals. Instead they founded a faux scientific journal called the *World Climate Review* (http://www.gcrio.org/DifHolding/GCRIO381.html). They also played their political cards with extensive Washington lobbying. Senator James Inhofe (of the Senate Environment Committee) has called the threat of catastrophic global warming "the greatest hoax ever perpetuated on the American people" (http://inhofe.senate.gov/pressreleases/climateupdate.htm). In 1997, the US Senate passed a resolution blocking adoption of the Kyoto Protocol by a vote of 95–0 (http://www.lycos.com/info/kyoto-protocol--united-states.html). The situation in Washington deteriorated further under President George W Bush, with the spectacle of Hollywood science fiction writer Michael Crichton appearing as an expert witness on climate before Congress and lecturing at the White House on global warming.

The denialists can also simply lie—with impunity, since their statements are not subject to editorial or scientific review. Creationists can deny the existence of transitional forms, dispute the reality of vestigial structures, and accuse scientists of faking the fossils of human ancestors (citing the Piltdown Man hoax as their "proof"). Warming denialists can plot points incorrectly in their temperature graphs or entirely omit the data from the past twenty-five years, when the major increases have taken place. They assert the existence of solar variations when sensitive orbital measurements show there are none, and some of them even make the remarkable claim that increased CO_2 is good for the environment (Gelbspan 2004:24)

There are also larger conceptual distortions that appear in most denialist literature. On the biological side, the distinction is blurred between the origin of life and its evolution. The origin of life is a difficult and largely unsolved problem, but once the mechanisms of inheritance are in place, the process by which all life is descended from common ancestors is relatively straightforward. Ever since Darwin, evolution has been about the origin of *species*, not the origin of *life*. Textbook changes or disclaimers promoted by creationists, however, often focus on the origin of life, as in the 1996 Alabama disclaimer "No one was present when life first appeared on Earth, therefore any statement about life's origin should be considered a theory, not a fact" (http://ncse.com/news/2001/11/state-board-education-adopts-another-evolution-disclaimer-00208).

On the climate side, one of the most common accusations is that climate models are complex and do not adequately include some factors, such as cloud formation. The truth, of course, is that we don't need numerical models to tell us that the world is rapidly warming, or to recognize the fact that the CO_2 content of the atmosphere is increasing by more than 3% per decade (see, for example, http://www.esrl.noaa.gov/gmd/webdata/ccgg/trends/co2_data_mlo_anngr.pdf). No model is required to show that, at the current rate of increase, atmospheric CO_2 will increase by 50% in this century relative to pre-industrial values—a harbinger of much worse climate disruptions to come (some estimates of changes by the end of the 21st century are in a recent IPCC report for policy makers: http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf).

Other myths and fallacies promoted by warming denialists include the misconception that carbon dioxide makes only minor contributions to greenhouse warming, relative to water vapor. In fact, it is the CO_2 (and increasingly methane) that determines the temperature structure of the troposphere. Water vapor amplifies the CO_2 greenhouse through positive

feedback. Another widespread denial concerns polar heating. It is in the high-latitude oceans that most of the extra heat is being deposited; hence the rapid melting of ice in both the Arctic and the Antarctic. The counterclaim that the Greenland and Antarctic ice caps cannot melt in less than several thousand years is based on the simplistic assumption that all the melting takes place from the surface. Much more important, however, is the accelerating movement of ice, lubricated by meltwater, generating huge icebergs that are eventually melted by warm seawater. Another common error is to confuse climate (long-term changes) with weather. Extreme weather in one location (such as heavy snow in the Atlantic seaboard) is not a valid argument against the reality of global warming.

The Role of Non-Profit Think Tanks

Non-profit institutes or think tanks have played critical roles in organizing the opposition to both evolution and climate change. The George C Marshall Institute was founded in Washington in 1984 primarily to support the Strategic Defense (Star Wars) Initiative, countering SDI opposition from scientists at the Union of Concerned Scientists (http://www.marshall.org/subcategory.php?id=9). The founders were prominent physicists associated with the Reagan administration: Frederick Seitz, William Nierenberg, and Robert Jastrow. In the late 1980s, they campaigned against environmental regulation by either denying that problems existed or opposing any government action to mitigate them. In 1989, the Institute issued its first report on climate issues, a book called *Global Warming: What Does the Science Tell Us?* coauthored by Jastrow, Seitz, and Nierenberg (see a summary of the main arguments in Jastrow and others 1991). This book blamed whatever global warming might be happening on the sun (see Oreskes and Conway 2010).

In the mid-1990s, the Marshall Institute became the prime critic of the UN Intergovernmental Panel on Climate Change (IPCC), a working group established by the United Nations and the World Meteorological Association (http://www.wmo.int/pages/index_en.html) in 1988. Contributors from over 130 countries included more than 1200 authors and 2500 expert reviewers. The assessment panels have operated under UN rules, in which unanimity is required; any member nation can in effect veto any statement of fact or recommendation. As a consequence, the reports have tended to be conservative and to lag behind the advances in climate science, just the reverse of accusations that "climate activists" hijacked the panels. For an insider's view of the IPCC system, see Stephen Schneider's (2009) *Science as a Contact Sport: Inside the Battle to Save Earth's Climate*.

The position of the Marshall Institute on climate change as presented on its website is deceptively simple (http://www.marshall.org/category.php?id=12). It concedes that "human activity, such as the burning of fossil fuels to power our homes and businesses, undoubtedly affect the global environment," but adds, "It is the extent of that effect and how it relates to changes in the modern climate which is the subject of current scientific debate". They say that their climate change program involves

> a critical examination of the scientific basis for global climate change policy. The intent is to promote a clear understanding of the state of climate science and assess the implications for public policy ... actions should flow from the state of knowledge, should be related to a long-term strategy and objectives and should be capable of being adjusted—one way or the other—as the understanding of human influences improves. (http://www.marshall.org/category.php?id=12)

From this good start they go on to deny the factual basis for climate change, asserting that we are unable to distinguish human-caused heating from "natural temperature variations." They concede that "naturally occurring greenhouse gases warm the earth by about 30°C" (http://www.marshall.org/subcategory.php?id=49), but they dispute that doubling the CO2 content of the atmosphere will increase this greenhouse effect. They conclude: "Because of the complexities of the climate system, there is no accepted estimate of the amount of warming due to the human emissions of greenhouse gases" (http://www.marshall.org/subcategory.php?id=49). Therefore they oppose any government action—for only the best scientific reasons, of course!

The Marshall Institute has exerted great influence in Washington based partly on the scientific stature of its founders, especially Frederick Seitz, who was once president of the National Academy of Sciences (1962–1969). Much of its funding has been from private industry and foundations, and it supports the anti-regulation positions of oil, gas, and coal industries (see Gelbspan 2004, Mooney 2005, Oreskes and Conway 2010). The Marshall Institute has interpreted its educational charter to apply primarily to the power brokers in Washington, providing seminars on environmental and defense issues for Congressional staffs and often organizing testimony at hearings (Oreskes and Conway 2010:56–57). Its positions generally parallel those of other conservative Washington think tanks, such as the American Enterprise Institute, the Heritage Foundation, and the Cato Institute.

The counterpart of the Marshall Institute among critics of evolution is the Discovery Institute in Seattle, and particularly its Center for Science and Culture (http://www.discovery.org/csc/). Bruce Chapman, who worked in the Reagan White House, founded the Discovery Institute in 1990 as a branch of the Hudson Institute (then in Indianapolis, now headquartered in Washington DC). The Center for Science and Culture (CSC), which has led the opposition to evolution, was founded in 1996. The CSC is the primary proponent of the wedge strategy, first articulated by Phillip Johnson, to undermine scientific materialism by attacking "Darwinism". Its objectives include sponsoring research on intelligent design (ID) to provide a scientifically respectable alternative to evolution—a rather spectacular failure, judging by the meager bibliography of published science on its website. Its members have written a number of books, however, primarily aimed at a non-scientific audience.

Like the Marshall Institute, the Discovery Institute's stated purpose is primarily public education. They promote ID to teachers, students, school boards, and lawmakers, producing educational materials, books and films. Americans United for Separation of Church and State writes, "[t]hough the Discovery Institute describes itself as a think tank specializing in national and international affairs, the group's real purpose is to undercut church–state separation" (http://www.au.org/media/church-and-state/archives/2002/05/the-discovery-in.html). One difference between the two Institutes is that the Discovery Institute sometimes tries to conceal its conservative Christian agenda, while the Marshall Institute is unapologetic about its environmental skepticism.

These think tanks pose as institutes for research and education, but in reality are little more than advocacy groups; however, to the public and politicians, they provide the cover of apparent scientific legitimacy. For example, both claim to showcase "scientific dissent" from the consensus scientific view relying heavily on the credentials of the signers rather than research findings.

Polls and Petitions

The opponents of evolution and global warming face a formidable challenge: to convince the public and decision-makers that there is significant dissent among scientists in two fields where in reality a strong consensus exists. They face nearly unanimous statements by scientific societies and academies of science all over the world affirming support for evolution by naturalistic processes and for anthropogenic global warming. To fight back, both denialist groups have used deceptive polling to support their claims of increasing scientific dissent and "theory in crisis."

The primary vehicle used to document dissent among scientists about global warming is called the Oregon Petition. It was organized by the non-profit Oregon Institute of Science and Medicine (http://www.oism.org/) and circulated twice, first between 1999 and 2001 and again from 2007 to 2008. The text of this petition reads:

> Proposed limits on greenhouse gases would harm the environment, hinder the advance in science and technology, and damage the health and welfare of mankind. There is no convincing evidence that human release of carbon dioxide, methane, or other greenhouse gasses is causing or will, in the foreseeable future, cause catastrophic heating of the earth's atmosphere and disruption of the earth's climate. Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the earth. (http://www.petitionproject.org)

Note that the wording refers only to "catastrophic heating of the earth's atmosphere," yet signers of this petition are often represented as questioning the reality of any greenhouse warming.

The marketing of this petition was clever and deceptive. It was mailed to an unknown number of scientists (probably several hundred thousand) with a supporting covering letter from Frederick Seitz, identifying him only as past president of the US National Academy of Sciences. Enclosed was a twelve-page article on "Environmental effects of increased atmospheric carbon dioxide" by Arthur Robinson, Noah Robinson, Sallie Baliunas, and Willie Soon (http://www.oism.org/pproject/s33p36.htm). This article followed the style and format of the *Proceedings of the National Academy of Sciences*, when in reality it was unpublished.

The original petition drive yielded 19 700 mail-in signatures. Only positive responses were solicited. Signers were asked to list an academic degree (about one third claimed to be PhDs) and to specify a discipline. Most were in engineering; only about one sixth identified themselves as trained in the atmospheric, environmental, or Earth sciences. There was no effort to determine which of them were active research scientists and no way for outsiders to check the authenticity of the names. An analysis of the list by *Scientific American* (http://www.scientificamerican.com/podcast/episode.cfm?id=john-rennies-seven-answers-to-clima-09-12-03) suggested that roughly 200 atmospheric or climate scientists might have signed.

In contrast, an often-cited study of published scientific literature by science historian Naomi Oreskes (2004) indicated solid support for the consensus view about global warming. She analyzed 928 abstracts of papers on climate change published between 1993 and 2003

in refereed scientific journals, finding that not one of these publications disputed the basics of climate change. A paper by Anderegg and others (2010) presented an analysis of publication and citation data for 1372 climate researchers and concluded that 97–98% of climate researchers support the science of anthropogenic climate change.

In 2001 the Discovery Institute began a similar effort to demonstrate that many scientists were disenchanted with biological evolution, which they like to call a field in crisis. A statement expressing skepticism about evolution was published in several magazines with requests for signatures from scientists who share this opinion. As of January 2011, 826 individuals from all over the world had signed the petition, which the Discovery Institute uses to support its claim that evolution lacks broad scientific support (http://dissentfromdarwin.org). Of course, what this list lacks is a denominator: 826 out of how many? In 2001, the year that the Discovery Institute first published this list with 100 signatures, the National Science Foundation listed 2.16 million scientists working in the US alone (http://www.nsf.gov/statistics/nsf05313/). Even the 2011 count is less that 0.04% of scientists working in the US ten years ago.

The "Scientific Dissent from Darwinism" statement is very simple.

> We are skeptical of claims for the validity of random mutation and natural selection to account for the complexity of life. Careful examination of the evidence for Darwinian theory should be encouraged. (http://www.dissentfromdarwin.org/index.php).

On their face, these are plausible statements: all scientists should be skeptical, and the basis of any theory should be re-examined as new evidence becomes available. However, for the past decade this list of "Scientific Dissenters from Darwinism" has been used by the Discovery Institute and others to support campaigns to "teach the controversy" and provide more "critical analyses of evolution." The Institute claims that this list supports the existence of significant scientific dissent from Darwinism, and that these dissenting opinions should be included whenever evolution is taught in the classroom.

Identifying the signers of this statement is difficult. Rather than providing their employers, people are frequently identified by the school they attended or temporary visiting appointments they may have held. Clearly if a person holds a science degree from a prestigious university, that carries more weight than if he is a financial analyst or runs a religious publishing house. Furthermore, there was no effort to screen the signatures by relevance of their discipline. Critics have pointed out that of the original 100 signatures, fewer than 20% were biologists, and even fewer were active researchers. Far from demonstrating dissent, these numbers are consistent with the claim often made that more than 99.9% of biologists in the United States accept evolution (see, for example, http://ncse.com/taking-action/project-steve).

Merchants of Doubt

Many of the strategies used by the opponents of both evolution and global warming are based on sowing misinformation and doubt. This approach is often called the "tobacco strategy", because tobacco companies used it effectively to delay health warnings and regulation of smoking. Historians Naomi Oreskes and Erik Conway (2010) have analyzed several examples of this strategy in their recent book *Merchants of Doubt: How a Hand-*

ful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming, and further supporting discussion is given by Chris Mooney in *The Republican War on Science* (2005) and Ross Gelbspan in *Boiling Point* (2004).

The tobacco industry in the 1950s could not disprove the link between smoking and cancer or heart disease, but they could undercut the science. Internal tobacco memos state "doubt is our product" (Oreskes and Conway 2010:15–16,34,288n129t). Big tobacco used science to fight science, funding a few pliable academic researchers, setting up non-profit foundations and organizations that released "scientific reports' and engaged in other forms of "education". Their efforts delayed effective government action by more than two decades. Other examples of the tobacco strategy include the denial of a relationship between production of CFCs (chlorofluorocarbons) and depletion of stratospheric ozone (fought by the chemical industry) and denial of a connection between smokestack emissions and acid rain (fought by electric utilities and coal companies).

Oreskes and Conway describe how a handful of famous and well-connected physicists such as Fred Seitz played a role in each of these disinformation campaigns. As one example, Fred Singer (2010) recently asserted that the science of ozone depletion is uncertain, replacing CFCs will be difficult and expensive, and the scientific community is corrupt and motivated by self-interest and political ideology—the same arguments used by global warming denialists (and not very different from some anti-evolution diatribes). Singer described his motivation in 1989 as follows: "There are probably those with hidden agendas of their own—not just to save the environment but to change our economic system. Some are socialists, some are technology hating Luddites; most have a great desire to regulate on as large a scale as possible" (Singer 1989:36–37). In 1991 he wrote that the real agenda of environmentalists was to destroy capitalism and replace it with some sort of worldwide utopian socialism—or perhaps communism (Oreskes and Conway 2010:134).

Conclusion

As the consequences of global warming become more apparent and more pressing, it is likely that educational policy in the United States will increasingly emphasize climate science in the curriculum. Indeed, climate change is present in the recently drafted framework that will serve as the basis for a new set of common state science education standards (NRC 2011). Along with this emphasis on climate science, however, will come a backlash, as the denialists turn their attention to combat the exposition of climate science, just as they have combated the exposition of evolutionary science. There have already been scattered incidents, as in Los Alamitos, California, where the local school board decided that climate change was a "controversial" issue in need of "balance" (Reardon 2011). As readers of *RNCSE* know, NCSE has been tremendously effective in challenging attempts to undermine the teaching of evolution. The strategies and tactics that NCSE has employed for years are now ripe to be deployed in the service of challenging attempts to undermine the teaching of global warming.

References

Anderegg WRL, Prall JW, Harold J, Schneider SH. 2010. Expert credibility in climate change. *Proceedings of the National Academy of Sciences* (USA). Available from: http://www.pnas.org/content/early/2010/06/04/1003187107.full.pdf+html

Gelbspan J. 2004. *Boiling Point*. New York: Basic Books.

Jastrow R, Nierenberg F, Seitz W. 1991. Global warming: What does the science tell us? *Energy* 16(11–12):1331–1345. Available from: http://www.sciencedirect.com/science/article/pii/0360544291900068

Mooney CR. 2005. *The Republican War on Science*. New York: Basic Books.

[NRC] National Research Council. 2011. *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington DC: National Academies Press.

Oreskes N. 2004. Beyond the ivory tower: The scientific consensus on climate change. *Science* 306: 1686.

Oreskes N, Conway E. 2010. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York: Bloomsbury Press.

Reardon S. 2011. Climate change sparks battles in classroom. *Science* 333:688–689.

Schneider S. 2009. *Science as a Contact Sport: Inside the Battle to Save Earth's Climate*. Washington DC: National Geographic Society.

Singer F. 1989. My adventures in the ozone layer. *National Review* 41(12):34–38.

Singer F. 2010. The ozone-CFC debacle: Hasty action, shaky science [Internet]; [cited 2011 Oct 1]. Available from: http://www.heartland.org/article/28896/The_OzoneCFC_Debacle_Hasty_Action_Shaky_Science.html

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REVIEW

Evolutionary Theory and the Creation Controversy

by Olivier Rieppel
Berlin: Springer, 2011. 204 pages

reviewed by J David Archibald

The author is a curator at the Field Museum in Chicago specializing in marine Mesozoic reptiles, but has also extensively written on the history and philosophy of science. Given his latter expertise, I had hoped for a volume that added a depth of understanding for the educated reader beyond some of the more superficial books on the creationism/evolution controversy that have appeared in recent years. Quite simply, the book is mistitled. It is far more about the history and philosophy of science in general and evolutionary biology in particular than about the creationism/evolution controversy.

Rieppel is at his strongest and most enjoyable when he weaves together the history and philosophy of biology and at his weakest and most tedious when he tries too hard to make a philosophical point. He does a fine job in chapter five in explaining why the important 20th-century philosopher of science Karl Popper thought "the total edifice of evolutionary theory was not true science" (p 100). The crux of the issue for Popper was that life on earth is unique, at least as far as we can now discern. As Rieppel notes, historical sciences such as evolution are deemed "descriptive" or "narrative." Fair enough, but as we can demonstrate today, evolution can be and is being tested in the laboratory and field. Hypotheses involving Darwin's natural selection are clearly testable, repeatable, often predictive, and likely universal. We may have only a rough outline of the history of life on this planet, but we certainly are becoming more and more competent in ascertaining how it occurred. Although life sciences are often called soft compared to physics, the study of the history of the solar system is just as narrative and descriptive as the study of the history of life. We understand the mechanisms or processes of both better than their histories.

Rieppel puts into focus the 19th-century ideas of evolution that had progressive change and adaptation as components, notably the work of Lamarck. It appears to me that the teasing apart of these two concepts may have played a role in the shift from viewing nature as a ladder of life (*scala naturae*) to a tree of life. Especially in its guise as the Great Chain of Being, life can be seen as arranged on an ontological scale (Lovejoy 1936:59) of perfection, from the lowliest hydra to plants to animals to humans and finally to the angels and God. "Progressive evolution along the Great Chain of Being and adaptation are two quite different aspects of species transformation, as was clearly recognized by the early French evolutionist ... Lamarck" (p 51). Of course, adaptation does not in and of itself imply evolution, but it does imply variations in form that preclude all existence from being neatly distributed along an insensibly graded ladder. Although Cuvier was a staunch creationist and no friend of Lamarck, his recognition of four branches of life suggested at least four broad types with differing adaptations. Cuvier's argument for four branches of life was a

soundly anatomically based thesis that suggested a more tree-like than ladder-like representation of nature.

Although I must admit that sometimes I am not sure why Rieppel veers off on a tangent about various philosophical matters, at other times he does a good job of explaining how various philosophical ideas have influenced our perception of nature in general and how science in particular operates. He has extensive sections reviewing the strengths and weaknesses of eminent 20th-century philosophers of science—Popper, Kuhn, Lakatos, and Feyerabend—notably in chapter seven. These can be hard going.

At times, the author takes us on philosophical joyrides that are difficult to relate to evolutionary theory. Chapter seven is a case in point. Another shorter example is page 107, where we go from geographic and genetic isolation in the process of speciation to a page-long lesson on magnets and iron filings as they relate to "counterfactual conditionals" (that is, conditional statements that specify what would be true if their antecedents were true) and back to geographic isolation. It is not that such topics are unimportant in pondering evolutionary theory, and why creationism and "intelligent design" are not science. They are, but they could have been presented in a more relevant, straightforward manner such as where Rieppel notes "... if design, purpose, and goal-directedness should permeate natural processes such as evolution, there is no room left for counterfactual conditionals to fail ... It seems to be impossible to imagine any state of affairs that could not be explained by the invocation of a Creator, or Intelligent Designer ... Creation, or Intelligent Design, explains everything not only infallibly, but also far too easily" (p 109). This is of course the major reason why such ideas fail the test of being science.

The text could have stood somewhat greater copyediting. Most errors are a dropped word or misspelling. One of the funnier errors reads "a polar bare male courts a polar bare female" (p 128)—quite cold out there without fur. Some other statements are simply wrong: "But then, the tiger is not only a large cat but also a carnivore—carnivore now no longer understood as an ecological kind ('carnivores') but as a genealogical kind ('Carnivora'), a kind of mammals [sic] that is marked out by the relation of common ancestry, and for that reason includes tigers and wolves but excludes eagles and pythons" (p 130). An animal can be a carnivore or carnivorous without belonging to the mammalian clade Carnivora.

Finally, the book is obscenely expensive, $189 for not quite 200 pages of text (without illustrations, which are not necessary). When one recognizes the publisher—Springer—the reason for this gouge becomes apparent. Springer is known for its outrageous book and journal costs. The price alone may discourage potential readers.

References

Lovejoy AO. 1942. *The Great Chain of Being: A Study of the History of an Idea*. Cambridge [MA]: Harvard University Press.

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REVIEW

Nature's Clocks: How Scientists Measure the Age of Almost Everything

by Doug Macdougall
Berkeley (CA): University of California Press, 2008. 288 pages

reviewed by John W Geissman

The concept of time is central to virtually all human endeavor. That of deep time, a phrase first coined by John McPhee to refer to time beyond the past 50 000 or so years that we can examine with radiocarbon dating, is central to our entire understanding of the history of the natural world in which we live and, more "locally" speaking, the history of the earth, our only home, and the history of life and its evolution on this home of ours. Karl Popper wrote in the preface of *The Logic of Scientific Discovery*: "There is at least one philosophical problem in which all thinking men are interested. It is the problem of cosmology: *the problem of understanding the world—including ourselves, and our knowledge, as part of the world*" (Popper 2003:xviii, emphasis in original). In *Nature's Clocks*, Doug Macdougall provides an exceptionally well-written and engaging description, for any "thinking man" (or woman), of how we know what we know about absolute age determinations and thus about our attempts to unravel the uncertainties of deep time. This book is very suitable for a general audience interested in the history of our planet, including the details of how geoscientists, based on absolute age determinations, infer the ages of specific geologic events (such as the extinction of the dinosaurs at the end of the Mesozoic Era) and the durations of specific processes (such as the formation of the Appalachian Mountains). In sum, the efforts to obtain accurate and higher precision age estimates have led to the establishment of the geologic time scale, a ruler, if you will, with which the endless details of earth history can be placed in an ordered and accurate fashion.

Unfortunately, space does not permit a summary of all of the components of *Nature's Clocks*, so let me highlight material in three chapters. Chapter 2, "Mysterious rays", is devoted to the discovery of radioactivity, and how, in particular, Ernest Rutherford followed the early research by Marie Curie and Henri Becquerel with an array of experiments that eventually led to his derivation of the "law" of radioactive decay. Macdougall's detailed account of how Rutherford recognized the implications of his research for calculating the age of geologic materials (that is, minerals, which constitute rocks), together with his encounters with Lord Kelvin and his first reports of his work on uranium-bearing samples in several lectures at Yale University in 1905, is one of the highlights of the book.

Although the reader is poised to read more about the implications of radioactive decay for deep time, and determining the age of the Earth, Macdougall does an about-face in chapter 3, "Wild Bill's quest", where the history of the development of radiocarbon dating by Willard F Libby, a nuclear chemist at the University of Chicago, and his colleagues, is impeccably and thoroughly described. A highlight of the chapter is Libby's "test" work on

a series of Egyptian artifacts, which came to be in his possession, in an unassuming box, two years earlier via a postdoctoral fellow, Jim Arnold, whose father, upon learning about his son's research, became most excited and "passed on his enthusiasm to the curator of Egyptian archaeology [Ambrose Lansing] at the Met" (that is, the Metropolitan Museum of Art in New York). Two years later, a piece of acacia wood from the tomb of the Egyptian pharaoh Zoser was taken out of the box and became the first ancient material subjected to radiocarbon dating. What follows is an absolutely breathtaking account of the excitement surrounding the recognition that the technique worked! Arnold, who actually was, in June 1948, measuring the number of carbon-14 decays per minute from the sample, quickly realized that the decay rate was statistically indistinguishable from that predicted for an age of 4650 years for Zoser's tomb, which the archaeological evidence strongly supported. Arnold remarked later, "One lives for such moments." A fascinating section in this chapter also reveals how, early on, radiocarbon dating exposed a lot of fakes in the world of Egyptian antiquities, which came as no surprise to many. Radiocarbon dating began to rewrite some 50 000 years of history.

Chapter 7, "Clocking evolution", nicely exemplifies how Macdougall is able to fluidly link several seemingly different subjects into a coherent account. It begins with the termination of the Mesozoic Era—the long-known end of the Cretaceous, when the demise of the dinosaurs allowed mammals to begin to dominate the planet. The hypothesis put forward by Luis Alvarez, his son Walter Alvarez, and other colleagues, that the extinction event defining the termination of the Cretaceous was caused by the collision of one or more asteroids with the earth over a short duration of time, is briefly discussed and then linked to the necessity of finding the smoking gun—the crater and associated impact material. This gets us to precise age determinations of the end of the Cretaceous and the impact crater itself, which is buried by younger sediment at the north end of the Yucatan Peninsula, but this time the age determinations are made using the potassium-argon decay scheme. We learn of the complicated steps involved in understanding the radioactive decay process, largely through the work of Alfred Nier, a physicist at the University of Minnesota, beginning in the mid-1930s. The steps include determining a half-life with great accuracy, developing the instrumentation necessary to conduct measurements of the radioactive isotope of potassium and its decay product, argon, and ultimately, in the 1960s, refining the approach by bombarding samples with neutrons in a nuclear reactor, so part of the potassium in the sample is converted into an isotope of argon, argon-39. This "argon-argon" isotopic age determination method is far more precise because the amount of potassium-40 in the sample does not need to be measured. Returning to the end of the Cretaceous, Macdougall describes the efforts to date the event with "impact spherules", droplets of melted rock formed from the asteroid impact, and distributed over much of the planet with other forms of impact-related sediment, right at the boundary, which turn out to be about 65.5 million years old. Macdougall writes, "Although the pathway to the correct age for the K-T boundary—including the use of standards—may seem a bit tortuous, it is important to understand because it illustrates the care necessary to get things right" (p 168).

That statement nicely summarizes Macdougall's passion for making certain that nothing of importance to the story of how we are able to measure the age of "almost everything" (from the cover of the book) is left out. Reading *Nature's Clocks* is guaranteed to improve

one's understanding of how the determination of absolute age estimates is carried out and one's appreciation of the associated intricacies.

References

Popper K. 2002. *The Logic of Scientific Discovery*. London: Routledge.

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REVIEW

Charles Darwin: After the Origin

by Sheila Ann Dean
Ithaca (NY): Paleontological Research Institution and Cornell University Library, 2009.
156 pages

reviewed by Sara B Hoot

Most biographies of Charles Darwin focus on his early years and the controversy surrounding the publication of the first edition of the *Origin of Species* in 1859. This book concentrates on Darwin's later years, from 1859 to his death in 1882. It is written in such a way that it is accessible to a general audience and includes appropriate full-color illustrations, many from Darwin's publications or notes, that enhance the text. Indeed, while modest in size (156 pages), this book is aesthetically pleasing enough that it could qualify as a "coffee table" book.

Charles Darwin: After the Origin would make a charming addition to any library and should be very helpful to educators who would like to tell a fuller story about Darwin's many accomplishments, some in quite esoteric fields (such as barnacles or earthworms and their effect on soils). The book is well-written and full of clear explanations of Darwin's precepts, a help to any person interested in his work who does not want to slog through his numerous publications, some of which go into agonizing experimental details (for example, some of his botanical books).

The book is organized into seven chapters that roughly follow the chronology of Darwin's life. The first chapter briefly covers Darwin's early life and sets the stage for the later chapters. The second chapter, "The 'Everlasting Old Origin'", discusses the birth of *Origin of Species*, including the contributions from other workers such as Wallace and Hooker to Darwin's thought processes and motivation. It has a very helpful section on the six editions of the *Origin*, including an annotation of the revisions and corrections that Darwin made with each edition.

Chapters 3 and 7 feature Darwin's botanical work, which he pursued off and on throughout his life. His botanical work (resulting in publication of numerous papers and books), whether on floral dimorphism and heterostyly, pollination in orchids, insectivorous plants, or plant movements and tropisms, include classic experiments that remain current today. Indeed, most modern biology textbooks include at least one of Darwin's experiments on plants (usually his early work on phototropism).

The remaining chapters focus on Darwin's work on various topics, each of which resulted in seminal publications: variation and artificial selection (resulting in *The Variation of Animals and Plants under Domestication*, 1868), human evolution (*The Descent of Man and Selection in Relation to Sex*, 1871), and expression of emotions (*The Expression of the Emotions in Man and Animals*, 1872). In the chapter on variation and artificial selection, it is

especially gratifying to read of Darwin's attempts to deal with the basic mechanisms of inheritance (that is, genes and DNA), which were unknown at that time. To grapple with this, he devised a construct which he called pangenesis—the inclusion of minute "gemmules" in cells and reproductive organs that were capable of transmitting characteristics. As he stated himself, "I am aware that my view is merely a provisional hypothesis or speculation; but until a better one be advanced, it may be serviceable …" Not such a bad construct, considering what was known at the time.

Throughout the book, one also encounters enticing glimpses of Darwin's personal relationships, with both colleagues and family. The involvement of his children in his experiments, the close notes he took of his children's development, even the notes on his dog Bob's "hothouse face" (noticeable body language revealing his disappointment at interrupted walks): all these convey the character of a man who was driven by his search for scientific truth but who also manifested warmth and integrity in his actions.

As you work your way through the book, it is amazing to see how sophisticated and contemporary Darwin's ideas were. He was indeed a "man ahead of his time" and sadly, many have still not caught up with him. This is further emphasized in the afterword written by WD Allmon (Cornell University), entitled "What did Darwin do?" This afterword effectively shows the effect of Darwin's work in evolution not only in the past and present, but also the future. It discusses the effects of Darwin's research not only on science and biology, but on such diverse areas as religion, literature, medicine, and psychology.

Charles Darwin: After the Origin makes Darwin's later works available in a easily accessed scientifically accurate text, helps us appreciate the historical settings of his research, and includes appropriate and well-placed illustrations—in short, a book that is well worth reading.

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REVIEW

Natural Selection & Beyond: The Intellectual Legacy of Alfred Russel Wallace

edited by Charles H Smith and George Beccaloni
New York: Oxford University Press, 2008. 482 pages

reviewed by Sherrie Lyons

Like many other scientists in Darwin's circle such as Thomas Huxley and Charles Lyell, Alfred Russel Wallace has been somewhat in Darwin's shadow, in spite of his independent discovery of the principle of natural selection. Historians of science have been drawing attention to the contributions of these men, and in the last ten years several good biographies have come out on Wallace. Nevertheless, this collection of essays is a valuable and welcome addition, elucidating the many different facets of this complicated and talented man. As Peter Bowler mentions in his foreword, Wallace made major contributions to evolutionary theory, extending its application to various areas such as the geographical distribution of species and coloration. He also disagreed with Darwin on various issues such as the analogy between artificial and natural selection. However, such disagreements spurred further research and debate, sharpening each man's thinking on several topics. Wallace also challenged many of the assumptions that underlay the Victorian faith in progress and scientific naturalism.

The book is organized into two sections. The first part, entitled "The world of nature", deals with Wallace's work as a field biologist and collector. The second part, "In the world of man, and the worlds beyond", explores the many other interests of Wallace. As the editors admit, this is an artificial separation, but it also roughly follows the chronology of Wallace's life, although his later interests were shaped by his experiences as a child and young man. Since this is an anthology, there is a certain amount of redundancy in the various essays concerning the basic biographical material, his travels, and his fieldwork. This is inevitable, but it also means that each essay stands alone. As the subtitle suggests and as I appreciated, the essays, particularly the essays on Wallace's biological work, emphasize Wallace's legacy for future research. While some caution must be exercised in not reading present-day knowledge back into the past, it is still useful to follow the trajectory of Wallace's many ideas. Much has been written on how Darwin's ideas continue to guide research in virtually all areas of biology, but this volume demonstrates that in many areas of field biology Wallace's ideas have been equally important. Most of the essays in the first part of the book are written by practicing biologists, and at times discuss modern research in more technical detail than may be of interest to a general reader. Yet they are all highly readable and accessible. The volume also has many interesting and often beautiful illustrations and photographs.

In the preface, the reader is introduced to Wallace from the perspective of a field researcher, and an introductory essay discusses Wallace's different places of residence. Andrew

Berry highlights the importance of collecting, in particular Wallace's beetle collection, to the making of the naturalist, which was critical to the development of the theory of evolution. As Wallace said, "Darwin and myself had, what he terms 'the mere passion of collecting,'—not that of studying the minutiae of structure, either internal or external. I should describe it rather as an intense interest in the mere variety of living things ... Now it is this superficial and almost child-like interest in the outward forms of living things, which, though often despised as unscientific, happened to be the only one, which would lead us towards a solution of the problem of species" (p 48–9).

Several essays deal with the specifics of Wallace's research. Norman Johnson discusses the evidence for direct selection for reproductive isolation known as the Wallace effect and Wallace's disagreement with Darwin over the role of hybrid sterility. What is the primary mechanism of hybrid inviability? Johnson follows the controversy to the present day. Two essays are devoted to color, which Wallace thought was one of the most important features under the control of natural selection and which he divided into five categories: (1) protective; (2) warning colors of (a) creatures specially protected, and (b) defenseless creatures mimicking the former; (3) sexual colors; (4) normal colors; and for plants, (5) attractive colors. This classification is still the basis for present-day research, which provides a depth of analysis beyond anything Wallace considered, and these two essays thus are quite interesting. Three more essays explore Wallace's contribution to biogeography (while not strictly its founder, Wallace can be considered the most important person in its genesis), his interest in glaciation, and his contribution to conservation and sustainability. As Berry points out, it is not surprising that naturalists such as Wallace have been so passionate about biodiversity. In our own day, EO Wilson, though perhaps most famous as the founder of sociobiology, describes himself first and foremost as a naturalist and collector, and devotes most of his time now to promoting biodiversity.Collectors value what they collect, and as Berry concludes, "we must ... *have and hold* ... the natural world if we are to understand it" (p 64, emphasis in original). In an age where biological research is increasingly dominated by molecular genetics, much can be learned from Wallace, who was one of the first people to articulate the value of biodiversity.

The second part of the book explores Wallace's many other interests. Peter Raby discusses Wallace's literary legacy while Gregory Claeys discusses Wallace's interest in Robert Owen's socialist vision of the ideal society. While Owen's influence on Wallace has been well documented, Claeys also shows how Wallace differed from Owen in several important ways. In an illuminating essay, Diane Paul points out that although Wallace is often portrayed as a fierce opponent of eugenics, such a view is not quite accurate. Like Galton, Wallace did not accept the Lamarckian view of the inheritance of acquired characteristics. He also agreed that the hereditary characteristics of the population needed improvement; only some form of selective breeding could accomplish such improvement. However, he disagreed with Galton on how this should be accomplished because of his different conception of how natural selection worked and also of what kind of improvement was needed. Thus Wallace rejected Galton's solution not because he thought it was immoral, but rather because it would be ineffectual. Instead, Wallace's hereditarianism, his radical egalitarianism, his views on the capabilities and conditions of women, and his rather conservative views on sexuality and marriage all contributed to a unique and complex view on the role of nature and nurture in improving society. Insightful essays by David Stack and Martin Fichman

explore Wallace's views on land naturalization and his support of the anti-vaccination campaign. Several essays address Wallace's involvement with spiritualism, offering different perspectives. The prevailing view until recently has been that Wallace changed his mind about the adequacy of natural selection in providing a complete account of human evolution because of his involvement with spiritualism. All of these essays provide a much more complex and nuanced view. As Charles Smith in the final essay argues convincingly, if we examine carefully Wallace's personal and professional development, his adoption of spiritualism was neither a change of mind nor a regression. Instead, as Wallace claimed, his new views that incorporated a guiding spiritual agent was rather an extension of natural selection in giving a complete account of the history of life. As Fichman (2004) argued in his biography of Wallace, spiritualism as well as science became nested within an overall theistic belief that increasingly dominated Wallace's thinking as he matured.

Bernard Michaux concludes his essay on biogeography in this volume by writing that he found Wallace "one of the most interesting and possibly most important of Victorian biologists" (p 185). I would expand that claim and assert that Wallace has to be one of the most interesting people in the history of science. This volume does an admirable job in elucidating the reasons why.

References

Fichman M. 2004. *An Elusive Victorian: The Evolution of Alfred Russel Wallace*. Chicago: University of Chicago Press.

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Sherrie Lyons has a PhD in the history of science and is the author of *Evolution: The Basics* (New York: Routledge, 2011), *Species, Serpents, Spirits, and Skulls: Science at the Margins in the Victorian Age* (Albany [NY]: State University of New York Press, 2009) and *Thomas Henry Huxley: The Evolution of a Scientist* (Amherst [NY]: Prometheus Books, 1999). She teaches at the Center for Distance Learning, Empire State College.

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REVIEW

Remarkable Creatures: Epic Adventures in the Search for the Origin of Species

by Sean B Carroll
Boston: Houghton Mifflin Harcourt, 2009. 352 pages

reviewed by Aubrey Manning

The "public understanding of science" is a familiar concern now, but I don't believe that it is enough to take it just at its face value. Certainly scientists need to be able to communicate their findings attractively and this ought not to be difficult, but we need to go far beyond this. The pursuit of science is a human activity involving the emotions as well as the intellect. Although at its best science will seek objective truths which can be verified and applied elsewhere, the process of getting there will often include all those elements of hope, frustration, satisfaction, despair, or delight that also accompany artistic endeavor. Thus it is a truly creative activity, and this is an important message to get across to a public who often feel distanced from science and scientists, regarding them as separated from other human concerns. For this, if for no other reason, illustrating science through biography has particular value by breaking down such unrealistic barriers.

Carroll's book is an excellent example and will be very useful for teaching because it does bring out the enjoyment and the adventurous side of science as the subtitle suggests. However, it is not primarily involved with the origin of species; it ranges more widely and more profitably. This is a history of evolutionary ideas over the last two centuries illustrated by the lives and the achievements of diverse individuals, many familiar but others less so. Carroll provides just enough commentary to keep continuity, but it is in the nature of this approach that at times we are led down various delicious individual byways. For, of course, so much great science comes from people who are in the grips of an obsession that keeps them going with determination despite much frustration on the way. Carroll begins with Humboldt's explorations of South America, which continent proved so crucial in the early inspiration of the three great naturalists who come next, Bates, Wallace, and Darwin himself. I was glad to read such an attractive account of Bates's work, bringing out how his discoveries of mimetic butterflies provided such wonderful evidence of natural selection in action in nature and helped Darwin to augment the sixth edition of the *Origin*. One cannot help wondering how biology would have developed if Bates and Wallace had stuck together in Amazonia. But something led to a split, and Wallace later went to the East Indies with the results well described here; Carroll captures well the contrasting personalities of Wallace and Darwin.

The evolutionary scene being set, as it were, Carroll gives us some of the stars of the heroic age of paleontology. There are good accounts of Charles Walcott and the Burgess Shale, Roy Chapman Andrews and the dinosaurs of central Asia. Much of this was large-scale expeditionary enterprise and yielded spectacular fossils, but two of the most fascinating of

Carroll's paleontologists are smaller scale operators but filled with that magnificent obsession mentioned above. First, from the early days, we have Eugene Dubois, born in 1858, who, completely captivated by evolutionary ideas, abandoned a promising medical career in Amsterdam in 1887 to look for "the missing link" (the fashionable term then—one wishes it were now extinct) in the Dutch East Indies. Years of searching in difficult conditions in the caves of Sumatra and Java yielded tons—literally—of fossils but eventually a single skull roof and a femur. Dubois named it *Pithecanthropus*; we know it as *Homo erectus* and Dubois's find is the type specimen. It was a crucial step towards understanding human evolution but "Java man" was well on the way to us, and we already recognized our closer relative *H neanderthalensis* whose discovery in 1856 (actually eight years earlier in Gibraltar but unrecognized) showed how un-unique we were. However, the earlier stages of our evolution in Africa had to wait another half century to be revealed by other fine obsessives, a whole family of them, the Leakeys. Carroll describes vividly their combination of dogged persistence, great skill, and sheer luck which brought us the australopithecines.

The way in which modern molecular biology has become integrated into evolutionary studies is one of the most inspiring examples of how science progresses with increasing knowledge. Carroll ends up with chapters on one really "remarkable creature"—Linus Pauling—who moved quite late into evolution having earlier won a Nobel Prize for his work on the chemical bond and later a second Prize for peace! Pauling and others who collaborated with him, notably Emile Zuckerkandl and Allan Wilson, developed a "molecular clock". This is based on the fact that as species diverge over time, tiny, non-functional mutations occur in the structure of proteins, like hemoglobin, which they share. Looking at well-established phylogenetic trees, one finds that, reasonably enough, the longer since they must have diverged the more their proteins differ. The clock can be calibrated when one has independently well-dated fossils, and all the evidence suggests that it runs very steadily. Thus we can estimate how distant was the last common ancestor of modern relatives. The molecular evidence and the paleontological evidence haven't always matched up at first—they certainly didn't for human ancestry. However, eventually the paleontologists came to accept that our split from the great apes was less than 5 million years ago, and the fossils to fill the gaps begin to emerge.

I suppose that it is the high points of paleontology that emerge most vividly from this book. Obviously you need to know where to look, but in the nature of things these are discoveries, important finds rather than planned pieces of research. Then advances follow as their significance is brought out through knowledge and insight. More than this, for Carroll shows us so clearly the human virtues of persistence—dedication we might call it—and enthusiasm that results in some great science. Especially when coupled with a deep love of the natural world, science is indeed revealed as a creative human activity.

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Aubrey Manning is Emeritus Professor of Natural History at the University of Edinburgh. With Marian Stamp Dawkins, he is the author of *An Introduction to Animal Behaviour* (Cambridge: Cambridge University Press, 1998), now in its fifth edition.

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REVIEW

Species, Serpents, Spirits, and Skulls: Science at the Margins in the Victorian Age

by Sherrie Lynne Lyons
Albany (NY): State University of New York Press, 2009. 245 pages

reviewed by A Bowdoin Van Riper

We imagine that the boundaries dividing science from pseudoscience are clear and well-marked, and that—even if we cannot define either one with the precision of a philosopher—we know the difference when we see it. Science, we tell ourselves, deals with the concrete, the real, the measurable, and the universal. Scientists, we solemnly repeat, formulate hypotheses only after they have gathered an abundance of facts, and test those hypotheses through repeatable experiments. Science works, in other words, just as the "Chapter 1" lessons in a dozen long-forgotten schoolbooks say it does. Except that it doesn't.

Scientists have long known—and over the course of the last half-century or so, historians of science have carefully documented—that real science is far more complex than the sterile, streamlined, step-by-step process described in textbooks. Not all scientific disciplines have the luxury of dealing with things that are tangible and directly measurable, or with processes that can be recreated at will on a laboratory bench. Then, too, scientists are human: as vulnerable to laziness, jealousy, ambition, pet ideas, and self-deception as the rest of us. The rigors of modern scientific practice—double-blind clinical studies, peer review, and take-no-prisoners questioning at meetings—exist, in large measure, to compensate for such human weaknesses. Physicist-turned-historian Stephen G Brush once asked, in a famous article in *Science* (1974), "Should the history of science be rated X?" The real story of what the great scientists of the past did behind closed laboratory doors is, Brush argued—tongue only half in cheek—a terrible example to hold up to impressionable young scientists-in-training.

Sherrie Lynne Lyons would disagree. A historian of evolution and allied sciences in nineteenth-century Britain and a biographer of Darwin's friend (and fierce defender) TH Huxley, she argues that the philosophical and methodological messiness of Victorian science—properly understood—sheds valuable light on the messiness of present-day science. *Species, Serpents, Spirits, and Skulls* is a substantial contribution toward such an understanding. Lyons's concern is with subjects from the outer edges of Victorian science: sea serpents, phrenology, spiritualism, and the spiritual dimensions (if any) of human evolution. The boundary between science and non-science was, she persuasively argues, fluid and sharply contested in Victorian Britain, and these subjects were the intellectual fields on which it was contested. Professional scientists (a group whose own boundaries were only beginning to take shape), amateur scientists, outright charlatans, and members of the general public all weighed in on them. The resulting debates touched not only on science,

but also on religion, philosophy, and law—not only on the nature of science, but also on the nature of proof and on the nature of the human spirit.

Organizing the book as a series of case studies, Lyons sketches the historical and intellectual background for each debate before teasing apart the arguments, the motives, and the stakes for each of the groups involved. The chapter on sea serpents, for example, begins with the discovery of plesiosaurus and ichthyosaurus fossils that, in the 1810s and 1820s, lent new plausibility to old legends. It quickly moves, however, into deeper conceptual waters: eminent geologist Charles Lyell's interest in sea serpents as evidence for his theories about the history of life, the desire of newly professionalizing scientists to establish themselves as arbiters of questions about nature, the status of eyewitness testimony (even when submitted as sworn affidavits) as scientific evidence, and the drive to find naturalistic explanations for the wondrous that manifested itself in science writing and in novels such as Jules Verne's *Twenty Thousand Leagues Under the Sea*.

The remaining case-study chapters differ in their particulars, but make broadly similar points. Lyons treats phrenology, the science of using the shape of an individual's skull as an indicator of their psychological makeup, as part of psychologists' attempt to separate their field from philosophy and establish it as an experimental science allied with biology. She shows—after a long, entertaining stripping-away of thick layers of trickery, deceit, and deception—why spiritualism (communicating, via mediums, with the spirits of the dead) attracted the attention and interest of late-Victorian physicists interested in the nature of energy and invisible electrical fields. The book's best chapters—not surprisingly, given the author's background—are those that deal with the evolutionary theory: with Alfred Russel Wallace's wrestling with the problem of the evolution of the human mind and moral sense, and TH Huxley's deep differences with Darwin over the tempo of evolutionary change. Lyons sketches the scientific and social backgrounds of her protagonists with admirable conciseness, showing how each came to the positions they defended so vigorously in their writings through the complex interplay of evidence, interpretation, and prior (or simultaneous) intellectual commitments.

Species, Serpents, Spirits, and Skulls is strongest when it immerses the reader in the particulars of Victorian scientific practice and personalities. The narrative flows smoothly, the explanations of unfamiliar scientific concepts are clear, and the stories are satisfyingly complex without becoming impenetrable, even to the general readers who are the book's intended audience. The introductory and concluding chapters, which use the case studies to make larger points about the nature of science, are less successful. A long exploration—fascinating, but a digression—of the contested relationship between fossils and ancient myths robs it of momentum, and Lyons's restrained, judicious narrative style (so effective in the case studies) makes it seem muted when it should be bold.

One of the beauties of the book, however, is that its case studies boldly and clearly advance its central point. Readers will come away convinced that that science in the mid-nineteenth century was (like science today) messy, complex, and far from the streamlined process outsiders imagine: an X-rated show, perhaps, but one well worth taking in.

References

Brush SG. 1974. Should the history of science be rated X? *Science* 183:1164–1172.

About the author

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