

# Missing Links: Eugène Dubois and the Origins of Paleoanthropology

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Examining the origins of various scientific fields may help to identify particular individuals whose thought, work, and discoveries have had a disproportionately large influence. Such individuals seem to serve as catalysts for a wider set of intellectual reactions, which then give rise to an entire field of study. In this paper, we propose explicit criteria for recognizing the founders of new fields. We contend that Eugène Dubois, best known as the man who found the “missing link” between apes and humans, should be recognized as one of the founding fathers of paleoanthropology.

Dubois’ contributions to the founding of this field have been previously explored by Theunissen,<sup>1</sup> Erickson,<sup>2</sup> and Haddon<sup>3</sup> from somewhat different perspectives. Erickson viewed Dubois’ role in the origins of paleoanthropology as being relatively unimportant. In this regard, Theunissen, Haddon, and the authors of this paper disagree. We maintain that Dubois’ discoveries, analytical approaches, theoretical framework, and strong personality had much to do with the creation of the field of paleoanthropology. It lends additional interest to

this analysis that in modern times Dubois has often been either completely disregarded as a minor figure or caricatured as an accidental discoverer and a paranoid eccentric<sup>4–7</sup> rather than seen as a towering genius.

## DEFINITION OF TERMS

In some ways, the birth or coalescence of new fields of science parallels the process of paradigm shifting and scientific revolution articulated by Thomas Kuhn.<sup>8</sup> Kuhn maintained that “crises are a necessary precondition for the emergence of novel theories,” usually at a time when scientists “are confronted by even severe and prolonged anomalies” (p. 77), by which he meant observations or discoveries that do not fit the field’s currently accepted paradigm or general theory. Kuhn wrote of the response to anomalous observations and described the way in which such evidence is ignored or denigrated until the weight of counter-evidence becomes too compelling, and until an alternative paradigm is offered. Thus, although no single set of evidence overturns a paradigm, it may be possible to identify one that acts as the trigger or catalyst for the rejection of an old paradigm. And, he maintained, “The decision to reject one paradigm is always simultaneously the decision to accept another.” Thus, the process

of rejection depends on the existence of both compelling counter-evidence and an alternative paradigm or formulation of the field.

In recent years, anthropologists have argued both for and against the applicability of Kuhn’s model to paleoanthropology.<sup>9,10</sup> Chamberlain and Hartwig<sup>9</sup> emphasize Kuhn’s recognition that scientific acceptance is won by a constellation of variables, including intuition, emotion, and intellect. Because paleoanthropologists are unable to conduct controlled experiments to clarify disagreements, Chamberlain and Hartwig think it is useful to recognize that “people [are] at the center of science” and argue that it is important to focus on the “ontology of science, or how it was actually and realistically done” (p. 43). In contrast, Cartmill<sup>10</sup> rejects Kuhn’s model as wrong because he cannot identify any Kuhnian paradigm shifts in paleoanthropology between 1930 and 1999. He argues that conceptual changes in science occur perpetually, not as punctuational events or revolutions.

The coalescence of new fields cannot occur as purely Kuhnian revolutions because fields that have not yet emerged have no existing paradigm to shift away from. However, the accumulation of anomalous observations—facts that do not seem to fit into any accepted paradigm—is clearly integral to the process, as is a growing self-awareness on the part of the participants that they are engaged in and with a “field of study.” We define a field of study as an area of intellectual endeavor that holds a common set of concerns, theories, and procedures or techniques that are intended to address a closely connected web of problems. However, a field of study is

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also a subtler entity because the phrase refers equally to an intellectual community that is recognized by its participants under a small number of names (or perhaps a single name) and that expresses its thoughts, progress, or attempts at progress in an explicit and historically recognizable form, as in books, journals, or conferences. We do not expect one person or one discovery to be wholly responsible for creating a new field in a revolutionary fashion, but neither do we believe that the acceptance of scientific theories ever proceeds by a purely objective process of evaluation.

### THE ROLE OF THE FOUNDER

The potential founders of new fields do not overturn the existing paradigm; instead they supply an initial paradigm that then encompasses a set of anomalous observations and vague ideas. By providing a theoretical framework that has previously been lacking, founders help unite a set of data, observations, or techniques into a single field of study. Founders fill in the missing links and by so doing create a new and cohesive network of facts, concerns, and theories that focus on common issues. The forging of the previously missing links may occur in a variety of ways, through tangible discoveries, new observations of already known discoveries, and even an insightful articulation of a set of concerns. Presentation of the information, including the way in which it is described, linked to other observations, and put into a context, is extremely important in the founding of a new field. What makes these new links powerful is both the quality of the observations and the integrity of the overarching paradigm or theory that is offered to encompass them. Logically, then, examining the careers and personalities of founders will also reveal critical aspects of how a particular field of science operates: what its implicit and explicit rules of proof are, what makes a theory either acceptable or controversial, and the identity or characteristics of acceptably credible proposers of theories.

To qualify as a founder of a scientific field, we suggest that an individual must be responsible for one or all of the following: a pivotal discovery, which, in paleoanthropology, may

take the concrete form of either fossils or artifacts; an innovative technique for the description or analysis of discoveries; a new framing of the problems or questions of the fledgling field; a broad dissemination of information or debate about the subject, which serves to make it a matter of wide concern; and the provocation of a general reaction or response from potential colleagues. This last point may require some explanation. Successful founding of a field requires not only individual actions but also the provoked reactions of potential colleagues. Others must pay attention to the work of the founder and consider seriously the innovations, discoveries, or interpretations the founder advocates. Ultimately, the field must come into being in some tangible way, such as the establishment of journals devoted to the new subject, the new appearance of broad synthetic works on the topic, the creation of regular international conferences, the coining of new names and terminology, or perhaps the creation of various honors, professorships, courses, or academic departments in the new field.

### DUBOIS' CONTRIBUTIONS

Do Dubois and his accomplishments meet these criteria? We review here only the most pertinent details of his life and work. Additional information and documentation for our discussion can be found in Shipman<sup>11</sup> or Theunissen,<sup>1</sup> as well as in the extensive Dubois Archives in Naturalis, in Leiden, the Netherlands.

The discovery most often linked to Dubois' name is the finding of the *Pithecanthropus erectus* fossils at Trinil, in Java, in 1891 and 1892. (These specimens now are generally called *Homo erectus*.) This find proved, to Dubois' satisfaction, that there had been an evolutionarily transition from apes to humans because the bones manifested characteristics of both apes and humans. Dubois' intention to find such a missing link was made explicit long before his discovery, via his 1887 lecture and 1889 publication.<sup>12,13</sup> His decision to search in the Dutch East Indies was part of an original framework constructed of both logic and facts, biogeographical, geological, and paleontological.

For his time, Dubois was one of the

very few who realized the tremendous potential of fossil discoveries to illuminate the evolutionary relationships among living forms. Although fossils were often used in the nineteenth century as chronological markers,<sup>14,15</sup> Darwin, Huxley, Haeckel, and the other great evolutionists of that century focused on comparative anatomy and embryology as the crucial evidence that evolution had occurred. However, notwithstanding the timely discovery of *Archaeopteryx*, which demonstrated a bird-reptile link, the general lack of fossil intermediates was acknowledged as one of evolutionary theory's weakest points, even in Darwin's *Origin of Species*.<sup>16</sup> In particular, the absence of a known link between apes and humans was troublesome.

Dubois was the only scientist of his day who deliberately set out to find a particular fossil hominid in a particular locale as the focus of a carefully constructed plan. He theorized that the missing link had lived in the continents where modern apes are found, favoring Asia because it is the home of the gibbon. Too, the existence of a fossil ape (*Sivapithecus*, then known as *Anthropopithecus*) in the Siwaliks was promising because he hypothesized that the Siwaliks and the Dutch East Indies west of Lombok (the islands of Sumatra, Java, Madura, Kalimantan, and Bali) were part of the same ancient biogeographic region recognized by Wallace.<sup>17</sup> If that interpretation was correct, then mainland southeast Asia and these parts of the Dutch East Indies would share a common fossil fauna, including fossil apes. Dubois especially favored Sumatra because it had many limestone caves suitable for preserving fossils.

The novelty of Dubois' approach cannot be overstated. Indeed, the nearly universal response of friends and colleagues to Dubois' plan to search for the missing link was to discourage him from a futile action that would ruin his career and endanger his life.<sup>18</sup> In the immortal words of a Dutch official who refused Dubois a grant for his searches, he should not throw his life away for "that crazy book of Darwin's."<sup>19</sup> However, Dubois did not coin the phrase "the missing link," nor was he the first to use it in the context of human evolution. The

earliest use of the term “missing link” to refer to a species transitional between apes and man that we have been able to identify in Asa Gray’s<sup>20</sup> writing in 1861.

German biologist Ernst Haeckel<sup>22</sup> laid important groundwork for the formation of the field of paleoanthropology in his widely read 1868 book, *Natürliche Schöpfungsgeschichte*, which was translated into English as *The History of Creation*<sup>21</sup> and sold in thousands of copies in numerous languages. In it, Haeckel included a speculative “pedigree of men and apes,” which presented evolutionary relationships among broad groups of the living races of humans (*Ulotrichi*, or woolly-haired men, and *Lissotrichi*, or straight-haired men), which were linked to the man-like apes (specified as chimpanzees, gorillas, orang-utans, and gibbons) through a purely hypothetical form called the Speechless men (*Alali*) or the Ape-Like men (*Pithecanthropi*). Haeckel’s<sup>23</sup> distinction between man-like apes and ape-like men was explicit:

These Ape-like Men, or *Pithecanthropi*, very probably existed towards the end of the Tertiary period. They originated out of Man-Like Apes, or *Anthropoides*, by becoming completely habituated to an upright walk, and by the corresponding stronger differentiation of both pairs of legs. The fore hand of the *Anthropoides* became the human hand, their hinder hand became a foot for walking. Although these Ape-like Men must, not merely by the external formation of their bodies, but also by their internal mental formation, have been much more akin to real Men than the Man-like Apes could have been, yet they did not possess the real and chief characteristic of man, namely, the articulate human language or words, the corresponding development of a higher consciousness, and the formation of ideas (p. 397–398).

Thus, the transitional ape-like man proposed by Haeckel personified the missing link, the unknown connection between humans and their closest living relatives, the apes. Exceptionally, Haeckel not only gave a formal name,

*Pithecanthropus alali*, to this hypothetical species but also specified its most important physical attributes.

When Dubois selected the name *Pithecanthropus erectus* for his new fossil species, he forged a decisive link between his discovery and Haeckel’s mainstream biology. Dubois thus nested human evolution into a broader set of evolutionary biology that applied to all organisms. Dubois was the first scientist to write a monograph on a hominid fossil that placed the extinct form in an explicitly and unequivocally evolutionary position between apes and humans.<sup>24</sup>

Before Dubois’ discovery, some fossil hominids (Neandertal remains) were known and one monograph had been written about them. The original Neandertal specimens were found in 1856. They were first publicly assessed on June 2, 1857, at a general meeting of the Natural History Society of Prussian Rhineland and Westphalia in Bonn by a local schoolteacher, Johannes Fuhlrott, and an anatomist, Hermann Schaaffhausen.<sup>25</sup> Schaaffhausen made three main points: the bones exhibited the normal morphology of a previously unknown type (that is, their unusual form was not pathological); the bones were ancient, fossilized; and it was a pity that a professional man had not been present at their discovery. Neither Schaaffhausen nor any of the other anatomists who spoke and wrote about the original Neandertal remains at this time placed them in an explicitly evolutionary context. This is hardly surprising, given that Darwin’s<sup>26</sup> *Origin of Species* had not yet been published. Indeed, evolutionary theory met with strong opposition in Germany, where the influential biologist Rudolf Virchow made great efforts to block acceptance of the new theory.

In 1863, Huxley<sup>27</sup> published his masterful *Evidence as to Man’s Place in Nature* and seized upon the Neandertal remains as a useful exemplar in his comparisons among monkeys, apes, and humans. But even Huxley, the arch-evolutionist, did not feel that the original Neandertal finds represented a transitional form lying between apes and humans on the evolutionary tree. He viewed them, rather, as being a very primitive race of humans, “the most pithecoïd of human crania yet discovered” (p. 205) that

did not “fill up or diminish, to any appreciable extent, the structural interval which exists between Man and the man-like apes” (p. 186).

The next hominid fossils of significance were found in 1886, when additional Neandertal remains were excavated at Spy d’Orneau, in Belgium. In terms of the excellence of the documentation and analysis of the discovery, the monograph by Fraipont and Lohest<sup>28</sup> on the Spy Neandertals must be considered a landmark publication. However, the greater part of their monograph concerned their attempts to determine the fossils’ affinities to one of the modern human races, not to assess Neandertals’ evolutionary position relative to the higher primates as a whole. They concluded that these bones “... do not yet supply us with the necessary material to come to the solution to a question which interests us to such a high degree: the phylogenetic origin of man” (p. 775).

Compare this approach to that taken in Dubois’<sup>24</sup> monograph, written in 1894. Dubois’ title was “*Pithecanthropus erectus*: Eine menschenähnliche Uebergangsform aus Java” or, in English “*Pithecanthropus erectus*, a man-like transitional form from Java.” Dubois’ primary concerns in the monograph were to give a new taxonomic name to the fossils he had found, provide an anatomical description to justify this name, and assess the fossil’s evolutionary position. Thus, he described the remains of *Pithecanthropus erectus* at length and compared them to the bones of its closest known relatives: the chimpanzee and the gibbon on one side and the human on the other. Unfortunately, he treated the geology, discovery circumstances, and other fauna in a cursory fashion, which fostered controversy over the antiquity of the fossils and their derivation from a single individual.

The discovery of a skullcap, indicating cranial capacity, and a complete femur, the primary structural support for the body, was fortuitous. This circumstance made it possible for Dubois to conduct a new type of analysis that would, eventually, lead to the major subspecialty of biological analysis known today as allometry, the study of size and scaling. Because Dubois believed that the femur and



skullcap were derived from a single individual, he was able to examine the ratio of brain size to body size, a novel mode of analysis that he was later to develop much more extensively. He intuited that, if the creature whose remains he had discovered was an ape, then its brain was too large for the body size indicated by the femur. Conversely, if it were a human, the creature's brain was too small for its body size. This intuition was followed by a metrical analysis that showed *Pithecanthropus* to have the proportions of neither an ape nor a man, but those of an intermediate ape-man. While the skullcap's estimated capacity of approximately 1,000 cc was well below the modern human mean, it also surpassed by a wide margin that of modern apes, which then was believed never to be larger than ~500–600 cc. Even though normal humans with brains of about 1,000 cc were known, these individuals were invariably of small stature. *Pithecanthropus* was not, for the femur approximated the length of Dubois' own. He stood 1.76 m tall, according to his identity card, and was a well-muscled, sturdy man. Another important point was the very close resemblance between the fossil femur and that of any modern human.

In his monograph, Dubois pioneered the analysis of ratios of brain size to body size, which was very modern in its emphasis on metrical and mathematical comparisons. He invented a method for estimating cranial capacity from incomplete remains and for estimating stature from a femur. Further, he used, for the first time, a purely evolutionary framework, the basic ape-human dichotomy, to evaluate a hominid fossil.

### REACTION TO DUBOIS' DISCOVERY AND WORK

The initial reactions to Dubois' bold contentions were negative. Dubois' preliminary presentation of the specimen (the published version of his third quarterly report of 1892 to the Department of Religion, Science, and Industry) was marred by an extraordinary remark appended by the editor: "This last conclusion [that the East Indies was the cradle of humankind] really does seem to have been made rather hastily."<sup>29</sup>

Another reader voiced his skepti-

cism in a mocking letter published in the flamboyant Indies newspaper, *Bataviaasch Nieuwsblad*. Because the editor, P.A. Daum, wrote nearly every article that appeared in his newspaper, using pseudonyms to make it appear as if he had other contributors, it seems probable that Daum also wrote this letter, concluding: "No, I am afraid that the esteemed Mr. Dubois, prejudiced because he has completely swallowed Darwinism, has gone too far, and has constructed a connection between the human femur and the monkey skull and molar where none ever existed." The letter, published on February 6, 1893, was signed "Homo erectus," the first use of this name in print.

This rejection of Dubois' conclusions was echoed by others. A German zoologist, Paul Matschie,<sup>30</sup> after reading only Dubois' third quarterly report of 1892, accused Dubois of creating a chimera out of the bones of three separate species. Even after reading Dubois' monograph, Léonce-Pierre Manouvrier<sup>31</sup> questioned the association of the three bones into one individual. However, Manouvrier's independent estimate of the cranial capacity of the skullcap agreed with Dubois', leading the Frenchman to suggest that the find might indeed be a transitional ape-man. Anatomist Wilhelm Krause<sup>32</sup> discussed Dubois' monograph at the Berliner Anthropologische Gesellschaft on 19 January 1895, promising to make short work of Dubois' claims to have found a missing link. He attributed the skullcap and tooth to an ape and the femur to a human. Rudolf Virchow<sup>33</sup> openly mocked Dubois' findings and evolutionary framework, attributing the skullcap to a gibbon and the femur to a human. Similarly, Lydekker,<sup>34</sup> Cunningham,<sup>35,36</sup> Keith,<sup>37</sup> Turner,<sup>38</sup> and other British scientists expressed their skepticism, as did Topinard<sup>39</sup> in France, ten Kate<sup>40</sup> in the Netherlands, and the Swiss anatomist Rudolf Martin.<sup>41</sup> Only Othniel C. Marsh,<sup>42</sup> a paleontologist in the United States, and Ernst Haeckel, in Germany,<sup>43</sup> applauded Dubois' conclusions.

Thus, before Dubois and his fossils appeared in Europe in the autumn of 1895, his ideas had been critiqued and challenged by a significant number of scientists. Dubois was aware of the uphill battle he faced, as is shown by

an undated list in his hand preserved in the Dubois Archives in Leiden, in which he charted those who supported and rejected his work in various ways (Figure 1).

### DUBOIS' RESPONSE TO CRITICISM

Dubois' response to the failure of his ideas to gain acceptance was remarkable and deeply indicative of his confidence, perseverance, and, not to put too fine a point on it, pig-headedness. He refused to let the argument die. Within weeks of his return to the Netherlands, he embarked on a campaign to defend his ideas and his *Pithecanthropus*. He attended numerous conferences and symposia, lecturing at nearly every major institution in Europe during 1895–1896. He exhibited the original fossils and allowed others to examine them; made his arguments persuasively in person; provided additional information about the geology and fauna of Trinil; and made metric comparisons between the Trinil femur and a large number of modern human femurs available in Paris.

By these actions, Dubois won a significant number of converts and made the evolutionary position of *Pithecanthropus* a major scientific topic. Between the autumns of 1895 and 1900, Dubois published 19 articles that dealt with *Pithecanthropus*, while his European colleagues published at least 95 papers on *Pithecanthropus*. There were, on average, almost two such publications a month. Clearly, this find and Dubois' vigor in defending it made human evolution and *Pithecanthropus* topics that could not be ignored.

A measure of the importance of Dubois' actions can be seen in his recognition. In 1896 Dubois was awarded the Prix Broca, a French prize, in honor of his contributions to anthropology, and in 1897 he was awarded an honorary doctorate in botany and zoology by the University of Amsterdam. Further, he was appointed curator of "Paleontologisch Mineralogisch Cabinet" at the Teyler Museum and director of the "Indische fossielen" (Indonesian fossils), the latter with funding from an act of the Dutch Parliament.

Moreover, the status of *Pithecan-*

	Calvaria	Femur	m.3	m.2
R. Virchow 1	Affe	M oder auch (Hylobatide)	A	A
W. Krause 2	A	M	A	
Walbyer 3	ohne allen Zweifel A (Hylobatide)	M	A oder M.	
Hamann 4	A (H. neohelvi)	M	A	
Ten Kate 5	A	M	A	
Punnington 6	M	M	M	
Turner 10	M	M	A wahrscheinlich (S.H.)	
Reith 11	M	M	A (orangutan) später M.	
Leisler 12	M (microc.)	M	M	
Paul Martin 6	M	M	M	
Matochie 7	M	M	M vielleicht	
H. Kolbe 8	unbestimmt	M	—	
A. Pettit 13	M später P	M	M	P
Topinard 14	M	M	A	
Harsh 16	P	P	P	
Manouvrier 15	P	P	P	P
Vehring 17	P	P	P	
Dubois 18	P	P	P	P
Verneau 19	P	M	P	P
A. Pettit 19	P			

Figure 1. Dubois' handwritten list detailing, in addition to his own opinion, the published opinions of 18 colleagues on the true identity of the *Pithecanthropus erectus* fossils. The list was probably compiled in or about early 1896. A = Affe or ape; M = Mensch, or man; P = *Pithecanthropus*, or a transitional ape-man. He also makes small notations in several languages: "microc" means "microcephalic"; "M oder auch A (Hylobatide)" means "Man also ape, allied to the gibbon genus *Hylobates*"; "ohne allen Zweifel" means "without all doubt"; "wahrscheinlich" means "probable, likely"; "vielleicht" means "perhaps"; "unbestimmt" means "undetermined"; "später" means "later." Finally, the numbers after each name refer to specific articles published between 1892 and 1895. The original of this document is kept in the Dubois Archives, Naturalis, Leiden, The Netherlands, and is reproduced here with permission.

*thropus* was a major issue at the Fourth International Congress of Zoology in Cambridge in 1898. Haeckel<sup>44</sup> gave a keynote address that outspokenly favored Dubois and his claim that *Pithecanthropus* was a valid missing link, saying

... as a relic of that extinct group intermediate between man and ape to which as long ago as 1886 I gave the name *Pithecanthropus*. He is the long-sought 'missing link' in the chain of higher primates.

The able discoverer of *Pithecanthropus*, Eugène Dubois, has not only convincingly pointed out his high significance as a 'missing link,' but has also shown in a very acute manner the relations which this intermediate form has on the one side to the lower races of mankind, on the other hand to the various known races of anthropoid apes . . .

For forming a correct judgment concerning this important *Pithecanthropus* and its intermediate position between the anthropoids and man, two features are especially valuable: first, the close resemblance of the femur to that of man, and second, the relative size of the brain . . . The capacity of the skull of *Pithecanthropus* is from 900 to 1,000 cc, therefore about two-thirds of the capacity of an average human skull. On the other hand, the largest living anthropoids show a capacity half as high as this—500 cc. So the capacity of the skull and consequently the size of the brain is in *Pithecanthropus* exactly midway between that of the anthropoid apes and the lower races of mankind . . . (pp. 470–471)

Another indication of the growing significance of Dubois' discovery can be seen in an unusual action taken at the conference. After his departure from the Indies, Dubois was able to keep a crew of men working at Trinil under the supervision of his sergeants Kriele and de Winter, but the Indies government planned to withdraw its support for this project starting in 1898. When this fact became known, a formal resolution was proposed and swiftly passed by Congress of Zoology. It praised the discovery of *Pithecanthropus* and urged the Dutch Indies government to continue excavation at Trinil "with the same thoroughness as in the Past."<sup>45</sup> Remarkably, excavations at Trinil were resumed for 1898–1900, although no new fossils of *Pithecanthropus* were forthcoming.

In 1899, German anatomist Gustav Schwalbe<sup>46</sup> deeply offended Dubois by publishing, without permission, a detailed analysis of the *Pithecanthropus* fossils in a new journal of which

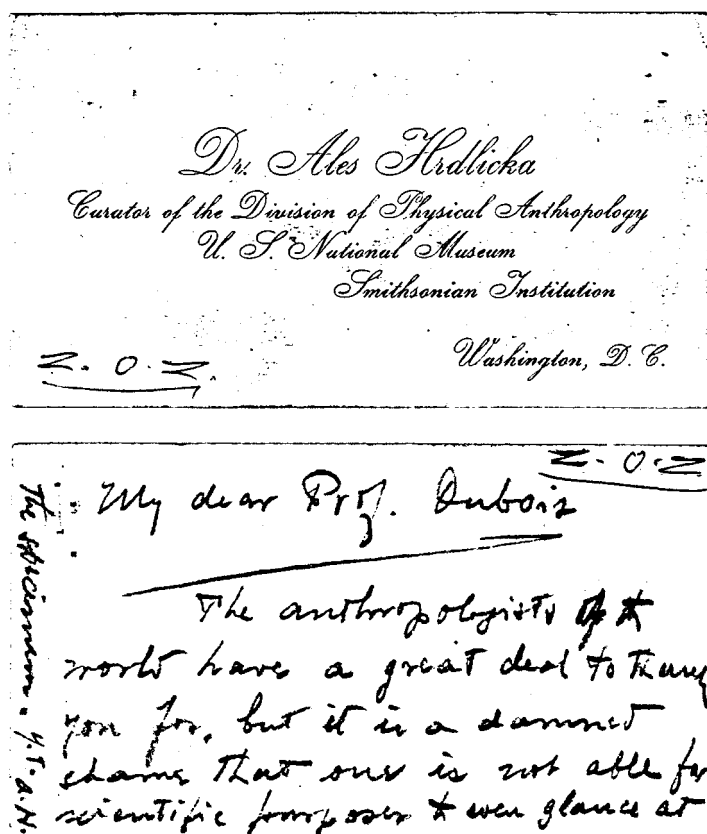


Figure 2. Aleš Hrdlička expressed his vexation at being denied access to the *Pithecanthropus* fossils on this calling card (top), which is kept in the Dubois Archives, Naturalis, Leiden, The Netherlands, and is reproduced here with permission. On the reverse side (bottom) Hrdlička has written:

"My dear Prof. Dubois

The anthropologists of the world have a great deal to thank you for, but it is a damned shame that one is not able for scientific purposes to even glance at the specimens. Y(ours) T(ruly)—A.H."

The notations Z.O.Z., which mean "please turn over" in Dutch, were unfortunately added at a much later date by an untrained curatorial assistant (personal communication, J. de Vos).

he was the editor: *Zeitschrift für Morphologie und Anthropologie*. The founding of the journal was all part of Schwalbe's campaign to break Virchow's anti-evolutionist hold on biology in Germany. In his premiere issue, Schwalbe<sup>46</sup> wrote an essay emphasizing the importance of the fossil record to understanding biology and comparative anatomy and took up several hundred pages of the first issue with a consideration of *Pithecanthropus*. Additional work on Dubois' fossils followed in later issues. Schwalbe proposed an evolutionary tree that incorporated not only apes, humans, and *Pithecanthropus*, but also Neandertals. Thus, Dubois' discovery and his interpretation of its evolutionary significance directly contributed to the founding of a new, pro-evolution journal in Germany that

treated humans as well as other mammals.

#### DUBOIS' PERIOD OF WITHDRAWAL

Dubois' reputation in the history of science was surely damaged by rumors of his mental instability. Between 1900 and 1920, Dubois went into a period of withdrawal during which he refused to let colleagues, including Aleš Hrdlička of the Smithsonian Institution, examine the *Pithecanthropus* remains (Fig. 2).<sup>47–50</sup> During this time, he published only one paper on *Pithecanthropus* per se,<sup>51</sup> a dramatic change from his earlier rate of publication. The end of this period was marked by the appearance of two publications on *Pithecanthropus*<sup>52,53</sup> and two others on fossil homi-

nids in general,<sup>54,55</sup> all of which Dubois wrote within a few years. In 1922, Henry Fairfield Osborn, president of the American Museum of Natural History, orchestrated an international protest about Dubois' reclusive behavior, which was lodged with the Royal Dutch Academy of Sciences.<sup>56</sup> Dubois was pressured to allow any qualified scientist to study his fossils. He capitulated; the first scientist admitted was Hrdlička, in 1923.<sup>57</sup> Dubois was urged to complete his long-delayed further publications on the remains and to make casts available for exhibit and study.

Despite florid rumors of Dubois' insanity, reconversion to religion, or bad scientific practice,<sup>58–60</sup> there is convincing evidence that Dubois did not suffer from debilitating mental illness. Between 1900 and 1923, Dubois published steadily in geology and hydrology, producing a total of 116 papers, or an average of five papers a year. Moreover, Dubois was the sole author of all but one of these papers. These publications are not those of a madman. However, Dubois' withdrawal from the field and his sequestering of his fossils engendered considerable resentment among other scientists.

#### APPEARANCE OF THE FIELD OF PALEOANTHROPOLOGY

The first general books dealing with paleoanthropology and human evolution began to appear just after the turn of the twentieth century, indicating that paleoanthropology was coalescing into a legitimate scientific field of broad interest. These books celebrated Dubois' finds and work. In 1904, W. L. H. Duckworth<sup>61</sup> published *Morphology and Anthropology* and endorsed Dubois' view of *Pithecanthropus* as a transitional ape-man. A few years later, in 1910, Alfred Haddon<sup>3</sup> published the *History of Anthropology*, "the first attempt at a history of Anthropology" (p. v). In this book, Haddon reviewed discoveries of various fossil hominids between 1700 (the Cannstadt cranium) and the Neanderthal skeletons uncovered in 1908–1909, commenting:

But these [other] investigations all fade into relative insignificance compared with the





sensation caused by the discovery made by Dr. Dubois in 1891 . . . . Dubois published his account [of the fossils] in Java in 1894, and since that date a vast amount of literature has accumulated around the subject . . . .

The English, as Dr. Dubois somewhat slyly noted, claimed the remains as human; while the Germans declared them to be simian; he himself, a Dutchman, assigned them to a mixture of both . . . .

The discovery of these human remains has had a very noticeable effect on anthropometry. Most of them are imperfect, some very much so; as in the case, for example, of the partial calvaria of *Pithecanthropus* and of the Neanderthal specimen. The remains are of such intense interest that they stimulated anatomists to a more careful analysis and comparison with other human skulls and with those of anthropoids (pp. 76–78).

A similar homage appeared in Arthur Keith's 1911 book, *Ancient Types of Man*,<sup>62</sup> in which an entire chapter is devoted to *Pithecanthropus* and Dubois' work. Keith told a charming (but not entirely accurate) version of the story of Dubois' discovery of the fossils at Trinil, endorsed Dubois' view that *Pithecanthropus* lay between humans and apes on the evolutionary tree, and affirmed that *Pithecanthropus* stood and walked fully upright. Both humans and *Pithecanthropus* fitted into Keith's evolutionary paradigm.

Similar sentiments about the importance of Dubois' discovery and the implications of the anatomical features of *Pithecanthropus* were reiterated in other works, such as Duckworth's<sup>63</sup> *Prehistoric Man*, von Buttel-Reepen's<sup>64</sup> 1913 *Man and His Fore-Runners*, Henry Fairfield Osborn's<sup>65</sup> *Men of the Old Stone Age*, Harold Peake and Herbert John Fleure's<sup>66</sup> *Apes and Man*, Arthur Keith's<sup>67</sup> *The Antiquity of Man*, and Marcellin

Figure 3. Anna and Eugène Dubois shortly before their departure for the Dutch East Indies in 1877. Photo courtesy of A. Hooijer-Ruben and Nelleke Hooijer.

Boule's<sup>68</sup> 1921 compendium, *Les Hommes Fossiles*. The plethora of books on human evolution that came out in the early twentieth century contrasts sharply with the paucity of books on the same subject before this time. The contents of these books give ample testimony that in large measure it was Dubois' finds and theories that triggered the interest in and acceptance of human evolution.

The praise lavished on Dubois' work in books written prior to 1922 contrasts sharply with the derisory assessment of his contributions to paleoanthropology from the 1930s onward. In this later period, Dubois is often characterized as irrational, unscientific, or mentally deranged. Many of the negative assessments of Dubois' work can be traced to the writings of G. H. R. von Koenigswald, with whom Dubois feuded bitterly from 1936 until Dubois' death in 1940.

The conflict began when von Koenigswald<sup>69,70</sup> announced in 1936 that he had found a new *Pithecanthropus* skull at Mojokerto. Almost immediately, Dubois<sup>71,72</sup> began to criticize von Koenigswald's work mercilessly. Dubois<sup>73–78</sup> repeatedly challenged von Koenigswald's identification of his fossils from Mojokerto and Sangiran as *Pithecanthropus* and, in one paper, accused his rival of distorting a particular skull during its reconstruction from fragments.<sup>70</sup> In an ironic parallel to the protest that ended his own period of withdrawal, Dubois<sup>79–83</sup> even attempted (unsuccessfully) to muster an international demand to bring von Koenigswald's fossils to the Netherlands where they would be accessible to other scholars.

For his part, von Koenigswald<sup>84–86</sup> perceived Dubois as a very real threat to his academic survival. When Dubois was elderly and infirm, the younger von Koenigswald<sup>87</sup> was attending international conferences, making influential allies (including Pierre Teilhard de Chardin, Franz Weidenreich, Helmut de Terra, and Hallam Movius), and presenting new and exciting fossils. Even after Dubois' death, von Koenigswald<sup>4,5</sup> persistently disparaged Dubois' work. By the time of von Koenigswald's death in 1982, he had done substantial harm to Dubois' reputation.

## CONCLUSION

Using objective criteria, we have assessed the role that Eugène Dubois played in founding the field of paleoanthropology. We find that his fossil discoveries were critical at the time they were made and still are important today. Dubois also invented several original analytical techniques that were widely adopted. More importantly, his writings forged a firmly evolutionary paradigm into which he fitted the transitional ape-man, *Pithecanthropus erectus*. Dubois drew connections to influential works on the theory of evolution even as he provided evidence demonstrating evolution's applicability to humans.

He shamelessly promoted his interpretation of the fossils, forcing his colleagues to rethink their too-ready rejection of his hypotheses. Given the harsh skepticism with which his monograph was greeted, Dubois' perseverance must be considered a major factor in the formation of paleoanthropology. A less stubborn man might have accepted the rejection of his ideas and stopped fighting; not so, Dubois.

Paleoanthropology sprang to life at the end of the nineteenth and the beginning of the twentieth centuries, as is shown by the founding of journals, the holding of conferences and symposia, and the unprecedented number of books and publications on human evolution, some of which were intended for the general public. The rate of fossil hominid discoveries and the attention paid to them increased dramatically, in no small part due to the resounding impact of Dubois' discoveries.

We conclude that Eugène Dubois deserves to be recognized as one of the founders of paleoanthropology. For those who ask why his contributions been so under-rated in recent times, we point to his difficult, unyielding, and uncompromising character. The same traits that made him successful at fossil-finding and persistent in the face of skepticism led him into numerous feuds with other scholars, some of whom discredited his ideas.

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We retain exact spellings within direct quotations. Where two dates are given for a publication that is based on a lecture or on an unpublished report, the later date indicates the time of publication and the earlier one the time of delivery of the lecture or report.

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