Producing Development: The Anatomy of Human Embryos and the Norms of Wilhelm His

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In 1875 the Göttingen anatomist Wilhelm Krause described what was briefly the most famous but soon became the most notorious human embryo of the last quarter of the nineteenth century. It was presented as deciding a heated controversy over embryology and evolution, but its status was debated in dozens of publications—until in 1882 anatomists finally agreed that it was the embryo, not of a human being at all, but of a bird. I shall reconstruct the remarkable history of Krause's embryo, but my larger concern is with the enterprise to which it fell victim: the making of modern human embryology. This was the achievement, above

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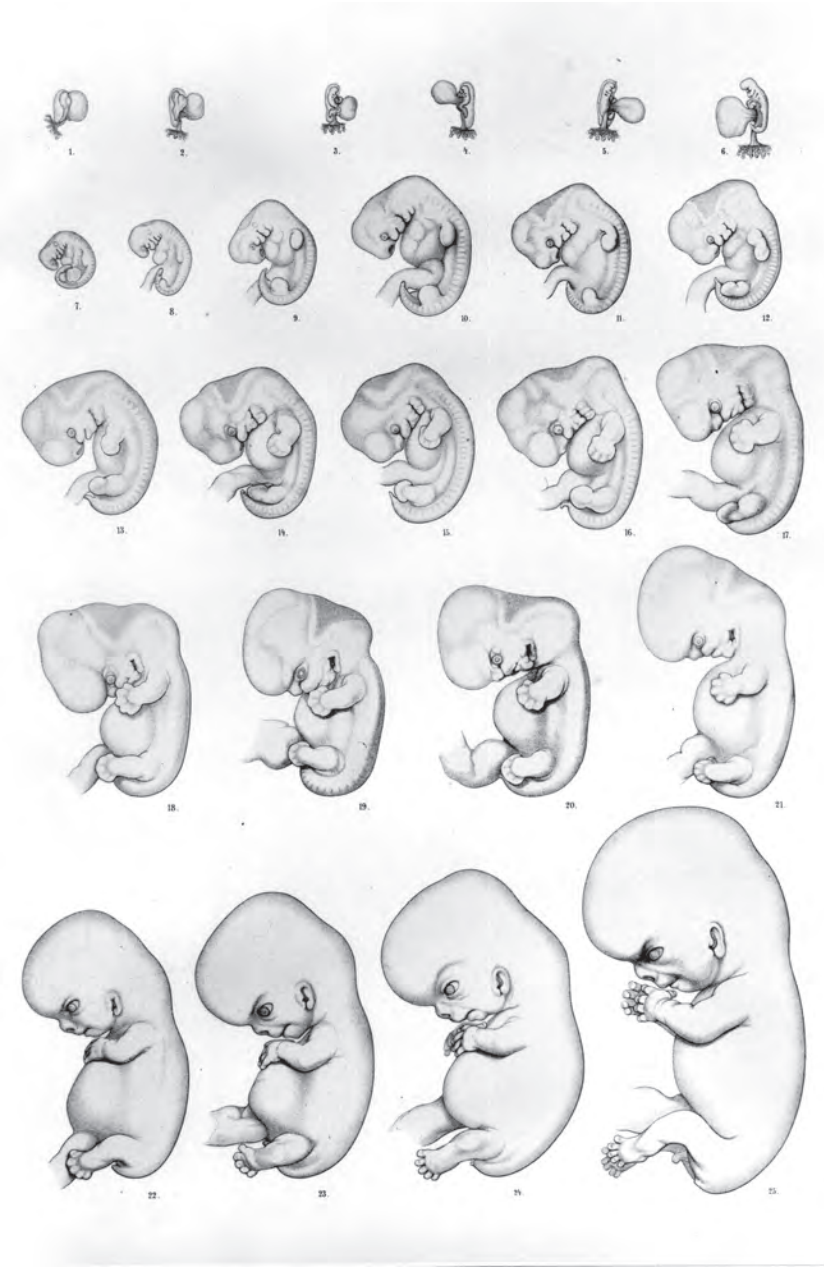

Fig. 1. The His *Normentafel,* from the *Anatomie menschlicher Embryonen,* lithograph by C. Pausch. (*AmE* 3, plate 10; courtesy of the Wellcome Institute Library, London.)

all, of the Leipzig anatomist Wilhelm His (1831–1904), whose *Anatomie menschlicher Embryonen* (Anatomy of human embryos) dramatically reformed the field.[1] The most important part of this work was a series of standard drawings of developing embryos advancing from the end of the second week to the end of the second month of pregnancy (Fig. 1). Development is usually taken for granted as what embryologists study; here, by analyzing the practical activities through which His constructed these norms, I investigate development as an effect that he labored to produce. Further, this article contributes to three historical literatures. First, studying a work conspicuously absent from recent historical writing on human embryos shows how and why His created human embryology as it would be practiced through the twentieth century. Second, highlighting this new human embryology restores a missing dimension to our picture of the transformation of the life and medical sciences between the post-Darwinian controversies and World War I. And third, analyzing closely the making of a particular atlas extends our understanding of this key genre of scientific standards.

Embryologists' major products have been developmental series: successions of progressively more advanced embryos, in the form variously of drawings, specimens in spirits, models, photographs, posters, sonograms, videos, and flip-charts. All work in embryology has depended on, and most has in its turn generated, these material representations of development. The representation of developing embryos has constituted the science by producing objects that embryologists could manipulate; displaying such series has communicated development widely. Yet historians of embryology have traditionally taken this labor for granted. Subordinating practical activities to theories of development, they have given us a history of concepts and problems with only perfunctory nods toward technique.[2] In particular, historians of science have emulated those embryologists who, defining their own practice as "experimental,"

1. Wilhelm His, *Anatomie menschlicher Embryonen,* 3 vols. (Leipzig: F. C. W. Vogel): vol. 1, *Embryonen des ersten Monats* (1880); vol. 2, *Gestalt- und Grössenentwicklung bis zum Schluss des 2. Monats* (1882); vol. 3, *Zur Geschichte der Organe* (1885). Though usually bound together, the three installments of text and figures are paginated independently and will be cited as *AmE* 1, 2, and 3. The first and third were accompanied by folio atlases; two series of eight wax models and a set of ten glass photographs were sold separately.

2. See Jane M. Oppenheimer, "Problems, Concepts, and Their History," and "Methods and Techniques," in *Analysis of Development,* ed. Benjamin H. Willier, Paul A. Weiss, and Viktor Hamburger (Philadelphia: Saunders, 1955), pp. 1–38. A recent collection edited by Scott F. Gilbert is significantly entitled *A Conceptual History of Modern Embryology* (Baltimore: Johns Hopkins University Press, 1994 [1991]). The textual equivalent of a developmental series is a narrative of development.

have since the late nineteenth century marginalized work considered merely descriptive of stages of development.[3] It is high time, by contrast, to follow those sociologists and historians who have paid attention to the mundane practices and material cultures of other medical and biological sciences, and to take the most routine work of embryology seriously.[4] Analyzing the construction of developmental series can demonstrate how by making, selecting, and ordering embryonic images, embryologists have materially produced development. Explaining the distribution of the most basic and widely important products of the science can account for the triumph of the embryological view of life and show how our own embryo-laden world was made.

A key work of human embryology will serve as an example. The extreme challenge of making developmental series for the relatively complex and inaccessible human embryos helps to make taken-for-granted practices explicit. And, as a routine part of the experience of monitored childbirth in the industrialized world,[5] and a potent means through which, over the last few decades, the politics of reproduction

3. On the problem of experimentalism in embryology, see Jane M. Oppenheimer, "Embryological Concepts in the Twentieth Century," in idem, *Essays in the History of Embryology and Biology* (Cambridge: MIT Press, 1967), pp. 1–61, on pp. 4–10; and Jane Maienschein, *Transforming Traditions in American Biology, 1880–1915* (Baltimore: Johns Hopkins University Press, 1991), which on pp. 111–13 also includes a rare analysis of the work of making a developmental series. More generally, see John V. Pickstone, "Museological Science? The Place of the Analytical/Comparative in Nineteenth-Century Science, Technology and Medicine," *Hist. Sci.*, 1994, *32:* 111–38.

4. See especially Ludwik Fleck, *Genesis and Development of a Scientific Fact,* ed. Thaddeus J. Trenn and Robert K. Merton, trans. Fred Bradley and Thaddeus J. Trenn (Chicago: University of Chicago Press, 1979); Adele E. Clarke and Joan H. Fujimura, eds., *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences* (Princeton: Princeton University Press, 1992); Robert E. Kohler, *Lords of the Fly:* Drosophila *Genetics and the Experimental Life* (Chicago: University of Chicago Press, 1994); Nelly Oudshoorn, *Beyond the Natural Body: An Archeology of Sex Hormones* (London: Routledge, 1994); Timothy Lenoir, *Instituting Science: The Cultural Production of Scientific Disciplines* (Stanford: Stanford University Press, 1997). I worked toward this view of scientific production in Nick Hopwood, "Genetics in the Mandarin Style," essay review of *Styles of Scientific Thought: The German Genetics Community 1900–1933* by Jonathan Harwood (Chicago: University of Chicago Press, 1993), *Stud. Hist. Philos. Sci.,* 1994, *25:* 237–50.

5. On the history of monitoring pregnancy, and the associated construction of the "fetal patient," see William Ray Arney, *Power and the Profession of Obstetrics* (Chicago: University of Chicago Press, 1982); Ann Oakley, *The Captured Womb: A History of the Medical Care of Pregnant Women* (Oxford: Basil Blackwell, 1984); Bettyann Holtzmann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, N.J.: Rutgers University Press, 1997), pp. 228–60; and Monica J. Casper, *The Making of the Unborn Patient: A Social Anatomy of Fetal Surgery* (New Brunswick, N.J.: Rutgers University Press, 1998).

have been fought out,[6] human embryonic and fetal images are attracting intense interest. Greater historical consciousness would enrich present debates. For though today series of developing human embryos are the dominant representations of pregnancy, they have been made for only the last two hundred years. Until the end of the eighteenth century, the human embryo existed in a kind of blind spot: in otherwise detailed anatomical illustrations and models it remained a symbol pointing toward the "coming child." In 1799, when enlightened medical reformers presented the fetus as embodying hopes for social progress and in need of protection, the Frankfurt physician Samuel Thomas Soemmerring produced a series of pictures showing in successive stages not just the growth but the development of the human body.[7] This was a momentous

6. On embryonic and fetal images and narratives in recent medicine and public culture, see Zoë Sofia, "Exterminating Fetuses: Abortion, Disarmament and the Sexo-Semiotics of Extraterrestrialism," *Diacritics,* 1984, *14* (2): 47–59; Rosalind Pollack Petchesky, "Foetal Images: The Power of Visual Culture in the Politics of Reproduction," in *Reproductive Technologies: Gender, Motherhood and Medicine,* ed. Michelle Stanworth (Cambridge: Polity Press, 1987), pp. 57–80; Sarah Franklin, "Fetal Fascinations: New Dimensions to the Medical-Scientific Construction of Fetal Personhood," in *Off-Centre: Feminism and Cultural Studies,* ed. Sarah Franklin, Celia Lury, and Jackie Stacey (London: HarperCollins Academic, 1991), pp. 190–205; idem, "Postmodern Procreation: Representing Reproductive Practice," *Sci. Cult.,* 1993, *3:* 522–61; Janelle Sue Taylor, "The Public Foetus and the Family Car: From Abortion Politics to a Volvo Advertisement," in ibid., 601–18; idem, "Image of Contradiction: Obstetrical Ultrasound in American Culture," in *Reproducing Reproduction: Kinship, Power, and Technological Innovation,* ed. Sarah Franklin and Helena Ragoné (Philadelphia: University of Pennsylvania Press, 1998), pp. 15–45; Carol Stabile, "Shooting the Mother: Fetal Photography and the Politics of Disappearance," in *The Visible Woman: Imaging Technologies, Gender and Science,* ed. Paula A. Treichler, Lisa Cartwright, and Constance Penley (New York: New York University Press, 1998), pp. 171–97; Valerie Hartouni, "Fetal Exposures: Abortion Politics and the Optics of Allusion," in ibid., pp. 198–216; Frances Price, "Now You See It, Now You Don't: Mediating Science and Managing Uncertainty in Reproductive Medicine," in *Misunderstanding Science? The Public Reconstruction of Science and Technology,* ed. Alan Irwin and Brian Wynne (Cambridge: Cambridge University Press, 1996), pp. 84–106; Michael Mulkay, *The Embryo Research Debate: Science and the Politics of Reproduction* (Cambridge: Cambridge University Press, 1997); Lynn M. Morgan and Meredith W. Michaels, eds., *Fetal Subjects, Feminist Positions* (Philadelphia: University of Pennsylvania Press, 1999).

7. Samuel Thomas Soemmerring, *Icones embryonum humanorum* (Frankfurt am Main: Varentrapp and Wenner, 1799). I am indebted for this perspective to Barbara Duden, *Disembodying Women: Perspectives on Pregnancy and the Unborn,* trans. Lee Hoinacki (Cambridge: Harvard University Press, 1993); idem, "'Ein falsch Gewächs, ein unzeitig Wesen, gestocktes Blut': Zur Geschichte von Wahrnehmung und Sichtweise der Leibesfrucht," in *Unter anderen Umständen: Zur Geschichte der Abtreibung,* ed. Gisela Staupe and Lisa Vieth (Dresden: Deutsches Hygiene-Museum; Berlin: Argon Verlag, 1993), pp. 27–35; idem, *The Woman beneath the Skin: A Doctor's Patients in Eighteenth-Century Germany,* trans. Thomas Dunlap (Cambridge: Harvard University Press, 1991). See further especially Esther Fischer-

transformation, but it was only a start. As late as the mid-twentieth century, many laypeople continued to understand pregnancy and abortion in nonembryological ways.[8] Nor was anatomists' work complete with Soemmerring: to embryologically enculturated eyes, his series only begins to convey a sense of true development rather than mere growth. Whereas embryologists today can still almost use descriptions of human embryos produced around 1900, scientists then already looked back on his atlas as grossly inaccurate.[9] The developing human embryo was first constituted as an object of scientific study in the late eighteenth century, but only in the late nineteenth was human embryology remade in its modern form. This innovation has, however, escaped not only cultural historians of embryonic and fetal images,[10] but also specialists in the history of embryology.

Historians of biology have investigated embryology as a paradigm of the life sciences in transformation around 1900. Between the 1870s and World War I, comparative research addressing grand evolutionary themes gave way to often-experimental analyses of focused problems in simpler systems.[11] To historians in search of the new biology, studies of the

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Homberger, *Medizin vor Gericht: Gerichtsmedizin von der Renaissance bis zur Aufklärung* (Bern: Hans Huber, 1983), pp. 222–92; Ludmilla J. Jordanova, "Gender, Generation and Science: William Hunter's Obstetrical Atlas," in *William Hunter and the Eighteenth-Century Medical World,* ed. William F. Bynum and Roy Porter (Cambridge: Cambridge University Press, 1985), pp. 385–412; Andrea Henderson, "Doll-Machines and Butcher-Shop Meat: Models of Childbirth in the Early Stages of Industrial Capitalism," *Genders,* 1991, *12:* 100–119; Michael Hagner, "Vom Naturalienkabinett zur Embryologie: Wandlungen des Monströsen und die Ordnung des Lebens," in *Der falsche Körper: Beiträge zu einer Geschichte der Monstrositäten,* ed. idem (Göttingen: Wallstein, 1995), pp. 73–107. For a fine "predevelopmental" series of wax models of human embryos, see Benedetto Lanza, Maria Luisa Azzaroli Puccetti, Marta Poggesi, and Antonio Martelli, *Le cere anatomiche della Specola* (Florence: Arnaud Editore, 1979), p. 226.

8. See Barbara Brookes, *Abortion in England 1900–1967* (London: Croom Helm, 1988); and on Germany see, e.g., the chapters by Karin Stukenbrock, Eduard Seidler, and Christiane Dienel in *Geschichte der Abtreibung: Von der Antike bis zur Gegenwart,* ed. Robert Jütte (Munich: C. H. Beck, 1993), pp. 91–168.

9. Franz Keibel, "Introduction," in *Manual of Human Embryology,* ed. idem and Franklin P. Mall, 2 vols. (Philadelphia: Lippincott, 1910–12), 1: xi–xviii, on p. xiii.

10. See the important survey by human embryologist Ronan O'Rahilly, "One Hundred Years of Human Embryology," *Iss. Rev. Terat.,* 1988, *4:* 81–128. By contrast, Karen Newman, *Fetal Positions: Individualism, Science, Visuality* (Stanford: Stanford University Press, 1996), skips the nineteenth century completely; Duden, *Disembodying Women* and "'Ein falsch Gewächs'" (both n. 7), acknowledges that Soemmerring had only begun to represent human development.

11. For an entry point to the historiography, see Maienschein, *Transforming Traditions* (n. 3). Important in mapping previously ignored terrain are Adele E. Clarke, "Embryology

relatively inaccessible and experimentally intractable human embryo seemed irremediably descriptive and unappealingly medical; historians of turn-of-the-century medicine, for their part, have concentrated on more clinically central sciences. But to many early-twentieth-century scientists, human embryology was a widely relevant new field of specialization boasting spectacular recent progress. In 1874 the Jena zoologist and evangelist of Darwinism Ernst Haeckel had proclaimed that "human embryos hold within themselves a greater treasure of the most important truths and form a deeper source of knowledge than most sciences and all so-called 'revelations' put together."[12] By preaching that during the first month of development noblemen were indistinguishable from dogs, Haeckel charged the degrees of similarity and difference between vertebrate embryos with interest and controversy. As I shall describe, in 1875 he deployed Krause's embryo against his archenemy His, who in the early 1880s fought back by reforming human embryology. His sought to take human embryos out of the hands of Darwinist popularizers, and away from clinicians too. Following His and goaded by Haeckel, over the next few decades human embryologists built an imposing edifice of knowledge and gained a certain independence. During World War I the Carnegie Institution of Washington founded a department devoted to the field under Franklin Paine Mall at Johns Hopkins University. An anatomical specialty between experimental embryology and the reproductive sciences, describing human development remained a prominent line of biomedical work into the mid-twentieth century.

As atlases, the books of Soemmerring and His are members of that class of developmental series through which embryogenesis has been most formally defined. The images they show are *norms,* standard embryos in terms of which scientists have learned to judge the species,

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and the Rise of American Reproductive Sciences, circa 1910–1940," in *The Expansion of American Biology,* ed. Keith R. Benson, Jane Maienschein, and Ronald Rainger (New Brunswick, N.J.: Rutgers University Press, 1991), pp. 107–32; idem, *Disciplining Reproduction: Modernity, American Life Sciences, and "the Problems of Sex"* (Berkeley: University of California Press, 1998); and Lynn K. Nyhart, *Biology Takes Form: Animal Morphology and the German Universities, 1800–1900* (Chicago: University of Chicago Press, 1995). For a survey, see Nick Hopwood, "Embryology," in *The Cambridge History of Science,* vol. 6: *Life and Earth Sciences since 1800,* ed. Peter J. Bowler and John V. Pickstone (New York: Cambridge University Press, forthcoming).

12. Ernst Haeckel, *Anthropogenie, oder Entwickelungsgeschichte des Menschen: Gemeinverständliche wissenschaftliche Vorträge über die Grundzüge der menschlichen Keimes- und Stammes-Geschichte* (Leipzig: Wilhelm Engelmann, 1874), p. xi.

normality, and stage of development of new individuals.[13] Norms of human development have changed, not only obviously—His provided twenty-five images to cover a period of pregnancy for which Soemmerring had given only six—but also, more subtly, in what they have been held to represent. For Soemmerring, each image was an ideal, the norm, "the most excellent or most perfect specimen among many."[14] In contrast, His's *Normentafel* shows not ideal types but specific individual embryos. (Literally a "plate of norms," *Normentafel* was usually rendered as "normal plate," but was often used in English without translation.) His supposed each drawing to characterize a developmental stage, but by the time Franz Keibel and Curt Elze published the next human embryonic *Normentafel* in 1908, these seriations of individual embryos were becoming unwieldy. They were superseded by the more flexible staging systems produced by embryologists at the Carnegie department, the "bureau of standards" for the science.[15] A history of human embryological norms should show how their construction and uses have changed over the last two hundred years. The importance of His's work in reforming human embryology makes it a strategic place to begin.

More generally, analyzing in depth the making of a particular atlas extends previous studies of these "bibles of the observational sciences."[16] We can understand atlas makers as working at nodal points in circuits of production. They collect "raw" objects and convert them, via successions of "rendering practices," into "working objects" that can be compared and generalized.[17] I shall outline how His constructed the embryos on

13. On atlases, see Lorraine Daston and Peter Galison, "The Image of Objectivity," *Representations,* 1992, *40:* 81–128; and on an embryological atlas, see Jane Maienschein, "From Presentation to Representation in E. B. Wilson's *The Cell,*" *Biol. Philos.,* 1991, *6:* 227–54. On biomedical norms, see Georges Canguilhem, *The Normal and the Pathological,* trans. Carolyn R. Fawcett and Robert S. Cohen (New York: Zone Books, 1989 [1978]); Michel Foucault, *The History of Sexuality,* vol. 1, *An Introduction,* trans. Robert Hurley (Harmondsworth: Penguin, 1981 [1978]), p. 144; and Volker Hess, ed., *Normierung der Gesundheit: Messende Verfahren der Medizin als kulturelle Praktik um 1900* (Husum: Matthiesen, 1997).

14. Soemmerring, quoted in Ludwig Choulant, *History and Bibliography of Anatomic Illustration,* trans. Mortimer Frank (New York: Schuman's, 1945), p. 302.

15. See O'Rahilly, "One Hundred Years" (n. 10); the "bureau of standards" tag, from the third director, George W. Corner, is on p. 93.

16. Daston and Galison, "Image" (n. 13), p. 81.

17. On collecting embryos, see especially Adele E. Clarke, "Research Materials and Reproductive Science in the United States, 1910–1940," in *Physiology in the American Context 1850–1940,* ed. Gerald L. Geison (Bethesda, Md.: American Physiological Society, 1987), pp. 323–50, on pp. 332–34. Clarke outlines how human embryos were collected by His's American students; I show that they built explicitly on his reforms. On "rendering practices," see Michael Lynch, "Discipline and the Material Form of Images: An Analysis of

which he worked by collecting an unprecedented number of early abortions, and rendering them through a sequence of disciplined operations into vivid embryonic images. The pivotal task in making an atlas is selection—judging which images to include and which to leave out—in His's case, especially those deemed abnormal.[18] Yet for atlases showing processes, individual pictures gain significance in relation to those that go before and come next; for atlases of development, it is crucial to solve not just the problem of selection but also the linked problem of sequence. I shall show how, by solving these problems, His converted a motley collection of drawings into a series representing normal human development. Critical comparison enacted new and more professionally exclusive standards of practice; these would sustain the norms, but only if other scientists could be persuaded to adopt them. We shall see in regard to Krause's embryo how selection became a focus of dispute, and how His's victory helped to reinforce his reforms and so make the norms collective. Sketching, further, how younger anatomists such as Keibel and Mall adopted the *Anatomie* as a model and the *Normentafel* as a framework will indicate both how they used His's work to create a new human embryology and how they began to revise his norms. In concluding, I suggest ways in which the analysis presented here could be extended and the notion of "producing development" applied more widely.

Constructing Embryos

When in the autumn of 1878 Wilhelm His embarked on a major study of the anatomy of human embryos, he was already an experienced and technically innovative embryologist holding one of the premier German chairs of anatomy at the University of Leipzig.[19] In the late 1860s, while still professor of anatomy and physiology in Basel, he had introduced one of the first microtomes able to convert an entire embryo into a series

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Scientific Visibility," *Soc. Stud. Sci.,* 1985, *15:* 37–66; and Michael Lynch and Steve Woolgar, eds., *Representation in Scientific Practice* (Cambridge: MIT Press, 1990 [1988]). For "working objects," see Daston and Galison, "Image" (n. 13), p. 85.

18. Daston and Galison designated the problem of selection as selecting a class of phenomena to be decisive for a discipline ("Image" [n. 13], p. 85); choosing which objects among them should represent the standard phenomena, they named the problem of choice (p. 86). At the risk of confusion, I prefer to call the latter the problem of selection, because this more readily evokes practical activities.

19. The main biographical studies are Wilhelm His, *Lebenserinnerungen* (Leipzig: printed as manuscript, 1903), reprinted in *Wilhelm His der Aeltere: Lebenserinnerungen und ausgewählte Schriften,* ed. Eugen Ludwig (Bern: Hans Huber, 1965); Rudolf Fick, "Wilhelm His†," *Anatomischer Anzeiger* (hereafter, *AA*), 1904, *25:* 161–208; Wilhelm Waldeyer, "Wilhelm His:

of sections, and at the same time pioneered a method of reconstructing three-dimensional drawings and models from the slices. It was an obvious move for an anatomist, professionally concerned primarily with the human body, to apply to human embryos the analytical techniques that he had earlier honed on more-accessible species such as the chick.[20] His's two major challenges were to collect specimens, and to render them into a form on which he could work. In collecting he brought together a miscellaneous assortment of objects and "framed" them as a set of human embryos; in rendering them he constructed out of globs in blood the embryonic images from which he would make the *Normentafel*.[21]

Nineteenth-century anatomists took early human embryos from three sources: usually, abortions and miscarriages; very occasionally, postmortems of pregnant women; and secondarily, existing collections in anatomical museums. It was difficult enough to obtain more-advanced embryos and fetuses, but embryologists counted specimens from the first two months of pregnancy as the greatest rarities. By placing himself at the center of a supply network of scientists and physicians, His collected seventy-nine such "treasures" in all, of which only five came from dis-

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Sein Leben und Wirken," *Deutsche medizinische Wochenschrift,* 1904, *30:* 1438–41, 1469–71, 1509–11; Wilhelm His (Jr.), *Wilhelm His der Anatom: Ein Lebensbild* (Berlin: Urban & Schwarzenberg, 1931); Hans Querner, "His, Wilhelm," *Dict. Sci. Biog., 6:* 434–36; Hugo Kurz, *Wilhelm His (Basel und Leipzig): Seine Beiträge zur Weltgeltung der Anatomie im 19. Jahrhundert* (Basel: Anatomisches Museum, 1992); Gottfried Zirnstein, "Wilhelm His (1831–1904)," in *Sächsische Lebensbilder,* vol. 4, ed. Reimer Groß and Gerald Wiemers (Leipzig: Sächsische Akademie der Wissenschaften; Stuttgart: Steiner, 1999), pp. 157–73. His is sometimes confused with his son of the same name, who discovered the bundle of His in the heart.

20. On His's chick work, see Nick Hopwood, "'Giving Body' to Embryos: Modeling, Mechanism, and the Microtome in Late Nineteenth-Century Anatomy," *Isis,* 1999, *90:* 462–96. More generally on the history of microtechnique, see Stefan Apáthy, *Die Mikrotechnik der thierischen Morphologie; eine kritische Darstellung der mikroskopischen Untersuchungsmethoden,* 2 parts (Braunschweig: H. Bruhn, 1896; Leipzig: S. Hirzel, 1901), 1: 35–140; and Brian Bracegirdle, *A History of Microtechnique: The Evolution of the Microtome and the Development of Tissue Preparation* (London: Heinemann Educational, 1978). His expressed pleasure at working specifically on human embryos because it allowed him to remain much closer to his anatomical profession than did the fish on which he had spent much of his time since finishing with the chick; see His to Friedrich Miescher-His (1811–87), 3 November 1878, Friedrich Miescher Papers, Universitätsbibliothek Basel.

21. I speak of "framing" embryos as Charles E. Rosenberg has written of "framing disease": see "Introduction: Framing Disease: Illness, Society, and History," in *Framing Disease: Studies in Cultural History,* ed. Charles E. Rosenberg and Janet Golden (New Brunswick, N.J.: Rutgers University Press, 1992), pp. xiii–xxvi. On alternative ways in which fetuses have been constructed in recent biomedicine, see Monica J. Casper, "At the Margins of Humanity: Fetal Positions in Science and Medicine," *Sci. Technol. Hum. Val.,* 1994, *19:* 307–23.

sected uteri, and one from an extrauterine pregnancy. More innovative than the scale of the operation was the way he linked means of preserving and transporting specimens, and the new methods of analysis for which he was campaigning with a moral duty to give material to him. He argued that these exceptionally valuable specimens must be subjected to destructive analysis with state-of-the-art techniques. Gynecologists, whom he claimed had been wasting or ruining the "precious objects" to which they had privileged access, should send them to him.[22]

In exchange, His named the embryos after the donors—named them, that is, not for the women from whose bodies they came, but for the medical men who had claimed them for science. Even after large numbers made the system of using the initial letters of donors' surnames too cumbersome, he continued scrupulously to credit his suppliers—or rather, to credit some of them. The system of exchange is thrown into relief by contrasting it with the way he dealt with material from another source. The midwives of Leipzig from whom he obtained twenty-two specimens were not named; perhaps he paid cash instead. One of their embryos, which arrived in his institute on a dark November afternoon in 1879, gave him "great pleasure": at 4 mm, the "very well conserved homunculus" filled "a yawning gap" between embryo M (2.7 mm), which his brother-in-law, the retired Basel pathologist and physician Friedrich Miescher, had given him in the early 1860s, and embryo A (7.5 mm), which he had received that same year from the collection of his Leipzig gynecologist colleague, Friedrich Ahlfeld. His was delighted that analysis of "this new precious object" confirmed and extended his previous work. Ultimately, it proved important enough to appear in the final *Normentafel,* but was known anonymously by the Greek letter α.[23]

In the late nineteenth century much more than today, even women who knew they were pregnant often did not interpret the contents of their wombs in embryological terms; in many cases the first and most significant thing that His and his suppliers did was to frame as embryos what had not previously been embryological objects at all. The embryos His studied were so early that there will frequently not have been any certainty that the women who aborted them were pregnant. As today, a very early spontaneous abortion was often indistinguishable from a late period, and might carry no special significance for the woman who

22. For "treasures," "precious objects," and the first of many appeals to gynecologists, which other anatomists amplified, see *AmE* 1: 4–5. The figure of seventy-nine is the sum of the embryos His mentioned receiving in the three parts of the work.

23. For the arrival of embryo α, see *AmE* 1: 100; for the quotes, see His to Miescher, 30 December 1879, Miescher Papers.

experienced it.[24] And it took weeks to be sure that even a missed period meant pregnancy. For a pregnant woman, the most important determinant of her relationship to the "fruit of her body" was whether or not she wanted to be pregnant; but neither the official discourse of the "unborn child" nor the images used by aborting women owed much to embryology. Focusing on restoring menstrual flow, the latter spoke matter-of-factly about "clotted blood" that needed thinning, and described abortion as "tipping out" a waste material.[25] Illegally aborted fetuses were generally disposed of by burial or burning, though others were, for example, left in hotel rooms rented under assumed names.[26] By contrast, some "wise women" kept a fetus preserved in spirits, midwives asked their clients to return with the "fetus" so that they could check that the womb was really empty, and fortunately for His, some women took aborted material to physicians.[27]

Collecting material from a wide variety of medical encounters with women's diverse histories of miscarriage, abortion, illness, and sudden death, His did not just homogenize the meaning of the objects, he also made them physically equivalent by treating them all in the same way. Writing to thank Miescher for hospitality during a holiday in Basel in the summer of 1878, he reported how he had been investigating embryo M, actually already relatively well known to him from using it in his Basel teaching:

> In the last few weeks my gratitude has, though, attached to a quite specific object, with which I have occupied myself most intensively, drawing, photographing, measuring, and microtoming. I have, you see, been working during this time on the little embryo (since married into the family), which you gave me for the collection years ago. [His's successor as Basel anatomist, Julius] Kollmann was so kind as to let me have it to work on, and I have, since in spite of the long time which it has been in alcohol it was still very usable, achieved a fair understanding of its exterium and interium. I have sent Kollmann some photographs and a small wax model, the first fruit of my efforts. Apart from

24. His urged physicians to search any late bleed for clumps of blood; see *AmE* 1: 3.

25. Cornelie Usborne, "Rhetoric and Resistance: Rationalization of Reproduction in Weimar Germany," *Soc. Polit.,* 1997, *4:* 65–89, on pp. 80–81.

26. James Woycke, *Birth Control in Germany 1871–1933* (London: Routledge, 1988), p. 91.

27. Cornelie Usborne, "Wise Women, Wise Men and Abortion in the Weimar Republic: Gender, Class and Medicine," in *Gender Relations in German History: Power, Agency and Experience from the Sixteenth to the Twentieth Century,* ed. Lynn Abrams and Elizabeth Harvey (London: UCL Press, 1996), pp. 143–75, on p. 167; and idem, "Abortion for Sale! The Competition between Quacks and Doctors in Weimar Germany," in *Illness and Healing Alternatives in Western Europe,* ed. Marijke Gijswijt-Hofstra, Hilary Marland, and Hans de Waardt (London: Routledge, 1997), pp. 183–204, on p. 196, where Usborne points out that

> this only $2^1/_2$ mm long creature, I have been lucky this autumn to get my hands on some further little people [*Menschlein*], so that I am for this winter richly supplied with material on which to work.[28]

Life scientists convert the inchoate and inaccessible results of their initial encounters with specimens, via sequences of disciplined rendering operations on successions of "representation devices," into vivid and widely distributed icons. Embryologists, specifically, have made developing embryos observable and knowable through the anatomical and graphic practices they have used to represent them.[29] His could not produce norms from the specimens as he received them, but had first to visualize embryos and make them comparable: he photographed, drew, measured, and microtomed. The resulting representations allowed him to display and communicate embryonic form: he sent colleagues photographs and models.

Compared to atlases of the previous generation, notably those by Victor Coste and Alexander Ecker,[30] the most important innovation of the *Anatomie* was that it brought human embryos into the microtome age. A decade after His's work on the chick, sectioning was becoming routine, but the rarity of human embryos had spared them the knife. He now insisted that it was time to "break with the tradition of so-called cabinet pieces," embryos kept whole in spirits for show—yet, alarmed lest misuse of the microtome alienate anatomists from the physical apprehension of

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returning with the "fetus" to an abortionist meant acknowledging more than just unblocking the flow of blood. It would be interesting to know at how early a stage such "fetuses" were handed in—i.e., whether much time was spent examining material from before the third or fourth month of pregnancy, when most abortions were carried out. His reproduced such medical case notes as he was able to obtain, and typically reported age, number of children, and the date of the last period before the abortion, and occasionally such information as husband's occupation or remarks on character. Tracing the unnamed women to the physicians' casebooks or, for the postmortems, to official records or newspaper reports, would be rewarding but difficult.

28. His to Miescher, 3 November 1878, Miescher Papers. On embryo M, see further *AmE* 1: 116–17. His reckoned he must have received the specimen in 1863, but it is likely to have been the "beautiful egg from the 3d week, a present from Prof. Miescher," referred to in Staatsarchiv Basel EA DD12, "Bericht über die anatomischen Sammlungen im Jahr 1861." Reports in this series show that Basel physicians, His's chief early suppliers, had been donating embryonic and fetal material since at least the late 1850s. He dedicated *AmE* 1 to the Basel Medical Society.

29. Lynch, "Discipline" (n. 17); Lynch and Woolgar, *Representation* (n. 17); Duden, *Disembodying Women* and "'Ein falsch Gewächs'" (both n. 7).

30. [J. J. Victor] Coste, *Histoire générale et particulière du développement des corps organisés* (Paris, 1849); Alexander Ecker, *Icones physiologicae: Erläuterungstafeln zur Physiologie und Entwickelungsgeschichte* (Leipzig: Leopold Voss, 1851–59).

form, he synthesized drawings of the sections to produce three-dimensional views and a couple of sets of wax models, which the Freiburg modeler Adolf Ziegler reproduced and sold.[31] We should be aware of the full novelty and complexity of His's representational activity because, first, he used the difficulty of these techniques to intimidate physicians into giving specimens; second, the authority of the *Anatomie* rested on the unprecedented depth of its analyses; and third, it was a multimedia event, displaying embryos for various audiences in the form of photographs, drawings, and models. But His actually established the norms by working on relatively simple drawings of surface morphology that he made in the first few phases of a sequence of rendering operations, and it is these that concern us here.

Because speed was of the essence, His asked his suppliers themselves to perform the first step, fixing specimens in alcohol to preserve the tissues from decay.[32] The next step was to "open" the embryo by removing the outer coat, including the opaque chorion; then the translucent amnion, the inner membrane that closely enveloped the embryo, would also be dissected away. Removing the chorion was in two respects decisive: first, since the embryo within might have stopped growing before its membranes, only once it was exposed could His assess its stage of development and normality; and second, "freeing" embryos of their means of connection to the pregnant woman created the persistent illusion that they develop by themselves.[33]

His now photographed and drew the embryos (Fig. 2). The advantage—and the disadvantage—of drawing over photography was, he reckoned, that a drawing, as the product of "mental work" separating significant from insignificant structures, involved "subjective elements" and was always "more or less an interpretation of the object"; a photograph, by contrast, he supposed to guarantee "absolute faithfulness" in reproducing all the details, and hence to be ideal as a record of embryos that would be cut up.[34] The institute photographer Th. Honikel sold a set of ten photographs on glass slides of the embryos described in the first installment of the *Anatomie,* and His demonstrated them at meetings—one, of embryo A, is published for the first time in Fig. 2A.[35] But drawings, often made from photographs rather than the usually already

31. Quote from *AmE* 1: 6. On His's models, see Hopwood, "'Giving Body'" (n. 20).

32. *AmE* 1: 3–4; 2: 3.

33. For critiques of images of fetal autonomy in recent biomedicine, see Petchesky, "Foetal Images" and other works cited in n. 6.

34. *AmE* 1: 6–7, on p. 6.

35. On the photographs, see Karl Bardeleben's review of *AmE* 1, *Deutsche medicinische Wochenschrift,* 1881, *7:* 44. For mention of a demonstration, see the report of Wilhelm His,

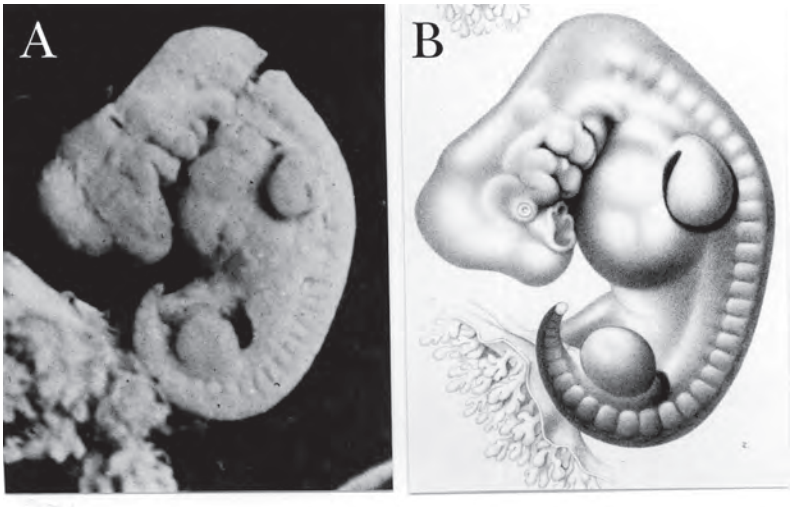

Fig 2. Embryo A, the ninth embryo in the *Normentafel*. (A) Photograph by Th. Honikel (courtesy of the Anatomisches Museum Basel). (B) Lithograph by C. Pausch, probably made using the photograph and His's preliminary drawings (courtesy of the Wellcome Institute Library, London); from *AmE* 3: plate 1*, this was intended to supersede an image that His had published in *AmE* 1: he pointed out features that he had in the meantime understood better, and stated that he had permitted himself to fill in the previously represented damage to the embryo (*AmE* 3: 257–58).

sectioned specimens, were His's most important working materials and finished documents. He highlighted the act of selection, but drawing was more complex: spots and marks taken to be incidental, such as specks of dirt, were filtered out; fuzzy, broken borders were upgraded into sharp, solid lines, including in this particular case filling in a couple of tears; a rather uniform grey was differentiated into markedly different tones to highlight elements of structure (Fig. 2B).[36] His did many of his own drawings, but the Saxon Academy of Sciences paid "a very careful artist" and lithographer, C. Pausch, to help. They used a drawing apparatus that by projecting an image onto the paper made the transfer more reliable,

"Ueber jüngere menschl. Embryonen und über die Allantois des Menschen," in *Tageblatt der 52. Versammlung Deutscher Naturforscher und Aerzte in Baden-Baden 1879* (Baden-Baden, n.d.), pp. 64–65, on p. 64.

36. On producing drawings from micrographs, see Michael Lynch, "The Externalized Retina: Selection and Mathematization in the Visual Documentation of Objects in the Life Sciences," in Lynch and Woolgar, *Representation* (n. 17), pp. 153–86.

and drew to known magnifications so that measurements could be converted into absolute values and hence compared.[37]

His collected specimens and rendered them directly into series of sections on microscope slides, and indirectly into the various "working objects" of human embryology. He converted them into what, according to his own analysis of the process of drawing, were views he had selected on the basis of his understanding of their structure. As we shall see now, different scientists with different understandings of the relations of form—or, in His's opinion, *mis*understandings—produced different representations. These being incompatible with his emerging norms of human development, he would have to exclude them.

Solving the Problems of Sequence and Selection

Germany's leading human embryologist in the generation after His, the Freiburg anatomist Franz Keibel, judged that the *Anatomie* had inaugurated a new era in human embryology by overcoming the two major obstacles to the analysis of human development: lack of material, and limits to scientists' powers of visualizing microscopically small and complex objects.[38] But to understand His's strategy we need to appreciate that accumulating new information, however impressively, was only half of what he was about. Crucially, the statement of purpose that opened the work announced a critical project:

> For human embryology the main difficulty lies, it is well known, in obtaining the necessary material. Dispersed in place and in time, one or another observer is offered a serviceable object, and so the body of empirical knowledge that science at present commands consists of fragments, which have been collected at very various times, by very various, and above all by very variously qualified, observers. To join such heterogeneous material together into a whole requires above all careful criticism, and this in turn can be carried out only by means of thorough observation.[39]

His did collect an unprecedentedly large number of early human embryos. In 1882 he boasted that of fifteen from the first three weeks of development, ten had passed through his hands.[40] But it is important to appreciate that in the short term he actually *reduced* almost as dramatically the number of human embryos available for anatomists' consider-

37. On Pausch, see *AmE* 3: 6; and on the drawing apparatus, later sold by Hartnack as an "embryograph," *AmE* 1: 8–10.

38. Keibel, "Introduction" (n. 9), p. xv.

39. *AmE* 1: 1.

40. *AmE* 2: 2.

ation. The fifteen excluded several previously recognized cases that he had dismissed as inadequately analyzed or pathological. Similarly, serial sectioning and plastic reconstruction did increase dramatically the thoroughness of investigations; but they also raised the price of admission to the field so sharply as to exclude nonspecialist participants, especially most gynecologists. Thus His did not simply overcome long and widely recognized obstacles: he sought to win assent to new standards of practice that would tighten anatomist-embryologists' grip on human embryology. On these rested his solutions to the problems of sequence and selection, and hence his norms.

What I call "the problem of sequence" might not seem a problem at all—except, for example, where hard work was needed in order to argue that two very different stages of a life cycle were developmentally related. Surely even without knowing the detailed pattern of human development, an embryologist could tell at a glance that a given specimen was more or less advanced—more or less like a baby—than another, and so arrange them in an ordered series? Anatomists reasoned in this way all the time; for a first approximation it was fine. But to formalize stages needed greater care. Given the complex and often unexpected paths by which structures developed, only painstaking investigation could rule out the possibility that an apparently more advanced feature was not a pathological condition becoming more pronounced. More routinely, deciding which of two similar embryos was more developed would always require discriminating judgment—even once a series of normal stages had been established. The problem of sequence was a real problem.

Embryologists had always approached human embryos via other amniotes, the chick and the more common mammals. It was accepted that the major developmental events—such as formation of the neural ("medullary") tube and the heart—were shared. His acknowledged that their relative sequence differed from one class to the next, but in the first part of the *Anatomie* he saw no difficulty in establishing numbered stages for human development corresponding to those he had earlier set up for the chick.[41] He did not use these stages further; they were scaffolding, with which he began to arrange the known human embryos, his own and those described by others, in developmental order. But the whole point of going to the trouble of studying human embryos was to discover to what extent they developed similarly to or differently from other vertebrates. In the end, norms of human development could be derived only from human embryos.

41. *AmE* 1: 147.

Time from fertilization might have provided a specifically human external standard, but in practice scientists considered estimates of embryonic age to be unreliable. This was partly because they were uncertain about the relationship between menstruation and ovulation. His subscribed to the then-dominant view that the two coincided, and he timed development from when the first missed period would have occurred, given a regular cycle.[42] Yet whatever the connection, such estimates were not only inevitably imprecise, they relied on women's testimony—which he did not trust. In an important step in the long process of scientific experts replacing pregnant women as authorities on pregnancy, His argued that embryologists needed to agree on criteria within the embryos alone.[43]

The embryos in the *Normentafel* would ultimately be arranged in order of increasing length, but it was not obvious at the outset that length could be used to mark developmental stage. Before His produced an embryological atlas he had published an anthropological one: before he measured embryos he had measured skulls, and as a veteran of craniometric debates he knew how controversial the apparently simplest measurements of complex objects could be.[44] Measuring the length of early embryos was especially problematic because they curled up to varying degrees through development. His took pains to define a standard length, and to show that its increase more or less matched developmental progress. He chose the longest straight line he could draw through the body over the line of greatest curvature. For embryos after "cervical bending" (the second and subsequent rows of the *Normentafel*) this meant the "nape line," from the cervical eminence to the lumbar region, justified as the simplest and quickest measurement. For embryos over 14 mm (roughly Figs. 19–25 of the *Normentafel*) the nape line ceased to be the longest straight line through the body, but His preferred it to longest-line measurements, which in these older embryos were too much at the

42. *AmE* 1: 166–68; 2: 72–86. On the overturning of the dominant view, see Victor Cornelius Medvei, *A History of Endocrinology* (Lancaster, U.K.: MTP Press, 1982), chap. 17; Stefanie Holle, "Die Wiederlegung des Postulates von der Gleichzeitigkeit der Ovulation und Menstruation bei der Frau: Klinische und histologische Untersuchungen im frühen 20. Jahrhundert" (medical doctoral dissertation, University of Erlangen-Nuremberg, 1984).

43. See Wilhelm His, "Zur Kritik jüngerer menschlicher Embryonen: Sendschreiben an Herrn Prof. W. Krause in Göttingen," *Archiv für Anatomie und Physiologie (Anatomische Abtheilung)* (hereafter *AAP*; before 1877, *Archiv für Anatomie, Physiologie und wissenschaftliche Medicin*), 1880, pp. 407–20; and *AmE* 2: 18–22. For an example of skepticism toward a woman's statement, see *AmE* 2: 90–91.

44. Wilhelm His and Ludwig Rütimeyer, *Crania Helvetica: Sammlung schweizerischer Schädelformen* (Basel: H. Georg, 1864). His had argued that even though the eye varied with

mercy of movements and distortion of the head. Before cervical flexure, the axial bending of the body made any measurement at best a rough guide to developmental stage.[45] What a ruler could not do, critical judgment would have to achieve, and so the problem of arranging the embryos in sequence overlapped the problem of selecting them.

Selection confronted the chronic problem that human embryologists obtained most of their material through the always potentially pathological process of abortion. Embryos recovered from postmortems were considered much more likely to be normal, but were few and far between. In spite of Georges Canguilhem's insight that the eighteenth century "made of the monster not just an object but an instrument of science," that in the nineteenth century "the monster is in the embryologist's jar where it serves to teach the norm," His set up his norms without reference to teratology: he summarily eliminated more than 22 percent of his embryos as major abnormalities—but this still left a good deal of sifting to do, especially of specimens described by others.[46] Case histories offered some clues. A good state of tissue preservation spoke for the health of the embryo, and made its analysis more rewarding, but it certainly did not exclude pathology. More informative was whether the stage of development of the embryo proper corresponded to that of the embryonic membranes; proportionality was a favorable sign, but again, by no means definitive (and itself relied on comparison). None of these features more than indicated normality—they were hurdles that His wished an embryo to clear before admission to the discussion. What was to count as normal could emerge only from comparing well-accredited embryos of clear provenance among themselves.

His advanced beyond a roughly arranged but still heterogeneous collection of embryos by subjecting every specimen to unsparing criticism and painstaking comparison with other cases.[47] This was the key

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the subject, measuring methods remained such that it could not be dispensed with; see Wilhelm His, "Beschreibung einiger Schädel altschweizerischer Bevölkerung nebst Bemerkungen über die Aufstellung von Schädeltypen," *Archiv für Anthropologie,* 1866, *1:* 61–74, on p. 69. He discussed the difficulties of using "measurement as the principle of the determination of norms" in idem, *Über die Aufgaben und Zielpunkte der wissenschaftlichen Anatomie: Rede, gehalten beim Antritt der anatomischen Professur der Universität Leipzig den 4. November 1872* (Leipzig: F. C. W. Vogel, 1872), pp. 9–10. On measuring in anthropology, see Stephen Jay Gould, *The Mismeasure of Man* (Harmondsworth: Penguin, 1984 [1981]).

45. *AmE* 1: 12–13; 2: 4–5; 3: 240.

46. Georges Canguilhem, "La monstruosité et le monstrueux," in *La connaissance de la vie,* 2d ed. (Paris: J. Vrin, 1969), pp. 171–84, on pp. 178–79. Further on monstrosities as "epistemic signposts," see Hagner, "Naturalienkabinett" (n. 7); and for His's discussion of malformations, *AmE* 2: 12–17.

47. *AmE* 1: 148–66.

selective practice: excluding those embryos that could not be made to fit, and leaving behind a consistent set of developmentally ordered specimens from which he would further select representatives for the *Normentafel* itself. To assess an embryo, His used the representations at his disposal, together with details of the sequence of rendering practices that he knew or presumed had produced them, as resources to drive exclusion. This propagated new standards simultaneously for embryonic material, for its analysis, and for those who would describe human embryos. According to His, embryological specialists analyzed good specimens well, but many dilettantes wasted time on poor specimens or ruined good ones through poor analysis. Between these extremes, minor reservations about state of preservation or normality hung over a specimen, while analyses could in various ways be incomplete or inadequate. But though he sometimes distinguished between an object to which he did not have access and its analysis, going beyond the published description was always conjecture. Embryo and analysis stood or fell together, and evaluating the quality of descriptions always meant evaluating the describer. Significantly, no living full professors of anatomy had described embryos that His excluded; rather, the describers nearly all fell into one of two classes. The first group were anatomists of the previous generation, often eminent and mostly dead. Among their embryos were the very well known handful that had figured in the textbooks for a long time. Parting might be painful, but in the name of progress they could be removed from the canon without dishonor. In stark contrast was the second group: gynecologists and other clinicians who had published a spate of early embryonic descriptions in the past few years, perhaps because changes in clinical practice had given them greater access to material. These were the most "variously qualified observers" whom His's brutal judgments sought to force into a choice: either become embryological specialists, or hand the embryos over to anatomists.[48]

In the first part of the *Anatomie* His excluded as in various ways unacceptable a large number of previously reported embryos. He complained to Miescher about the "very healthy" "reading stomach" needed

48. For surveys of anatomists and gynecologists, see Hans-Heinz Eulner, *Die Entwicklung der medizinischen Spezialfächer an den Universitäten des deutschen Sprachgebietes* (Stuttgart: Ferdinand Enke, 1970); and of anatomists, Nyhart, *Biology* (n. 11). Most of the scientists and physicians mentioned in this paper have entries in *Biographisches Lexikon der hervorragenden Aertzte aller Zeiten und Völker,* ed. August Hirsch, 6 vols. (Vienna: Urban & Schwarzenberg, 1884–88); Julius Pagel, *Biographisches Lexikon hervorragender Ärzte des neunzehnten Jahrhunderts* (Berlin: Urban & Schwarzenberg, 1901); and/or *Biographisches Lexikon der hervorragenden Ärtzte der letzten fünfzig Jahre,* ed. Isidor Fischer, 2 vols. (Berlin: Urban & Schwarzenberg, 1932–33).

to cope with the "interminable" and very uneven literature, but he refused to follow the "barbaric" custom he reckoned to be widespread among the young generation, of reading and citing only one's own work and the annual report of the previous year's publications.[49] It was crucial to consider every description, and where appropriate to give a reason for discarding it—for ignoring even analyses that he regarded as outdated or inadequate would have allowed them to haunt a field that he sought to clear for his own atlas.

His rejected embryos because they were insufficiently fixed—the "mistreated" specimen of Vienna gynecologist Hermann Beigel and Berlin ear-nose-and-throat specialist Ludwig Löwe had been stored in water and glycerine for a long time.[50] He dismissed descriptions, such as Berlin ophthalmologist C. G. Schwabe's inaugural dissertation of the previous year, where no figures were presented. He would not consider embryos that lacked measurements, such as one described by the late Giessen anatomist Carl Wilhelm Ludwig Bruch in the mid-1860s, and explained two other discrepancies as the result of incorrect or approximate information on magnification.[51] We have seen that drawings, for His, were not mechanical reproductions of evident structure: while a specialist's understanding of his material would shine through a picture, the drawings of a scientist inexperienced in observing human embryos would tend to be unclear. Old work of "father of modern embryology" Karl Ernst von Baer and the Dutch anatomist J. L. C. Schroeder van der Kolk fell to this criticism, but compared to the gynecologists they got off lightly. His made an example of the Munich obstetrician Carl von Hecker, with whose "description as with the figure one can do little, and both surely contain much misunderstanding. . . . It is to be regretted that Hecker did not hand this preparation over to his [anatomist] colleague Th[eodor] Bischoff [a pioneer of mammalian embryology], whose investigation would surely have brought much more fruitful results." A very recent description from the recently deceased Beigel was "almost even more uncertain" than Hecker's.[52] Occasionally, His used what he knew of an embryo's history to offer mitigating arguments in its favor. In two cases, he resolved differences by invoking poor access: in one, the embryologist

49. His to Miescher, 30 December 1879, Miescher Papers.

50. *AmE* 1: 148. The gynecologists Ahlfeld and Karl Breus had themselves complained about Beigel and Löwe's description; see Karl Breus, "Gynäkologie und Geburtshilfe," *Wiener medizinische Wochenschrift,* 1878, *28:* 454; Friedrich Ahlfeld, "Beschreibung eines sehr kleinen menschlichen Eies," *Archiv für Gynäkologie,* 1878, *13:* 241–48, on pp. 246–47. Löwe had habilitated in anatomy; see Pagel, *Lexikon* (n. 48), cols. 126–27.

51. *AmE* 1: 151–52, 158, 161.

52. *AmE* 1: 160–61.

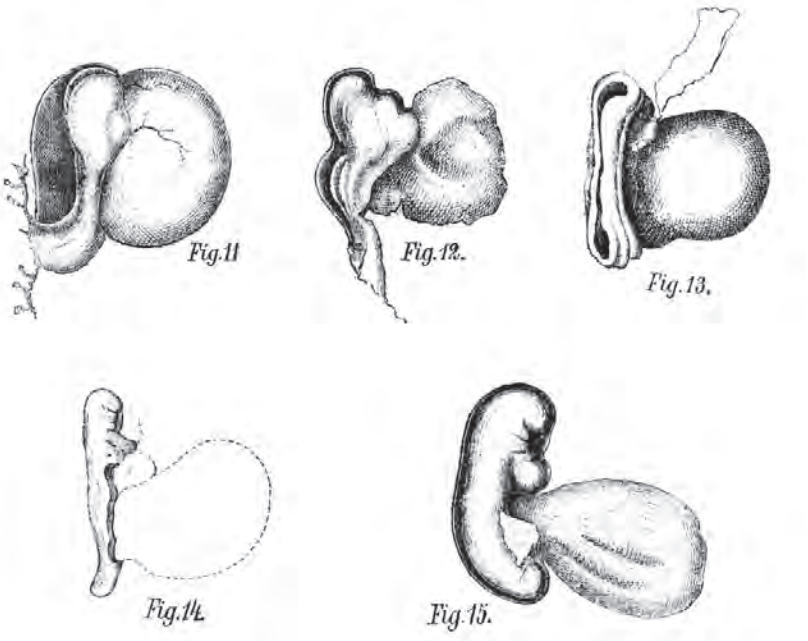

Fig. 3. A preliminary attempt to order embryos in the first month of development. (From *AmE* 1, Figs. 11–15.)

had not been able to study the specimen fresh; and in the other, retired Glasgow professor of anatomy Allen Thomson had had to observe a specimen outside his own laboratory, in bad light, and without touching it with an instrument.[53]

His's critical work began to establish a series of embryos of steadily increasing length and degree of development. He took stock by redrawing five selected early embryos, four his own and one Thomson's, to the same magnification and in the same orientation—a maneuver that made comparison as straightforward as possible (Fig. 3). This was effectively a preliminary attempt at a *Normentafel,* and three of the embryos reappeared in the final version. He concluded that "the agreement, or rather the regular progress in the dimensions, of these five embryos offers a warrant that we are dealing in these cases with normal relationships, and that the scale of sizes they represent can be used as a starting point for the

53. *AmE* 1: 149–50, 153. On Thomson, whom His respected and consulted to find out more about the embryos he had described several decades earlier (*AmE* 2: 34), see L. Stephen Jacyna, ed., *A Tale of Three Cities: The Correspondence of William Sharpey and Allen Thomson,* Supplement 9 to *Medical History* (London: Wellcome Institute for the History of Medicine, 1989).

assessment of other fruits."[54] By critical selection, His had proved himself able to establish human developmental order. As he worked, he not only began to set up embryonic norms, as an embryologist he normed himself.

In the second part of the *Anatomie,* His took those embryos from the first month that remained in the net, added nearly as many again that he had collected in the intervening two years, and continued the process of selecting and ordering.[55] In the youngest class, before cervical bending, he now had thirteen cases: three of Thomson's embryos, four that he had described in 1880, and six new specimens, one of these before the stage of actual embryo formation. He drew, or redrew, all but one of the embryos at the same magnification, compared them, and arranged them into groups based on length and shape (Fig. 4). Then he went through the rows of embryos in turn, justifying his grouping and seeking to explain discrepancies. While the embryos of the top four rows showed steady progress in size, they fell into two distinct groups with respect to general form: some had convex backs, but others were deeply concave. His concluded that the transition from one form to another was not developmental, but resulted from mechanical pressure on the amnion, possibly exerted by the anatomist opening the chorion. In these circumstances, greatest length was an unreliable measure, but he showed that by using head length he could produce the arrangement in the figure. He did not evaluate the explanation for these differences that would be accepted a quarter-century later, that embryos with dorsal flexure, or kinking, were "under all circumstances abnormal":[56] having succeeded in producing a consistent arrangement, he had no grounds for eliminating them. But he did not hesitate any longer in discarding three old and well-known embryos from famous embryologists that had barely made it through the first cull. One of Coste's, which the great authority Albert Kölliker of Würzburg had himself seen and described in his standard textbook as "incontestably the most perfect and most exactly observed of all human embryos of early periods,"[57] had to be set to one side because in His's view inadequate measurements left its size uncertain. He had tried to save this specimen by contacting Paris to see if it could be

54. *AmE* 1: 158.

55. *AmE* 2: 23–63. On "Formen vor Eintritt der Nackenkrümmung," see specifically pp. 31–43.

56. Franz Keibel and Curt Elze, with contributions from Ivar Broman, I. August Hammar, and Julius Tandler, *Normentafel zur Entwicklungsgeschichte des Menschen* (vol. 8, *Normentafeln zur Entwicklungsgeschichte der Wirbeltiere,* ed. Franz Keibel) (Jena: Gustav Fischer, 1908), p. 23. Franklin P. Mall agreed with Keibel; see his review of Keibel and Elze, *Normeltafel,* in *Anat. Rec.,* 1908, *2:* 368–71.

57. Albert Kölliker, *Entwicklungsgeschichte des Menschen und der höheren Thiere,* 2d ed., 2 parts (Leipzig: Wilhelm Engelmann, 1876–79), 1: 307. The whole textbook was given the date of the second installment when it appeared, but I wish to keep the chronology clear.

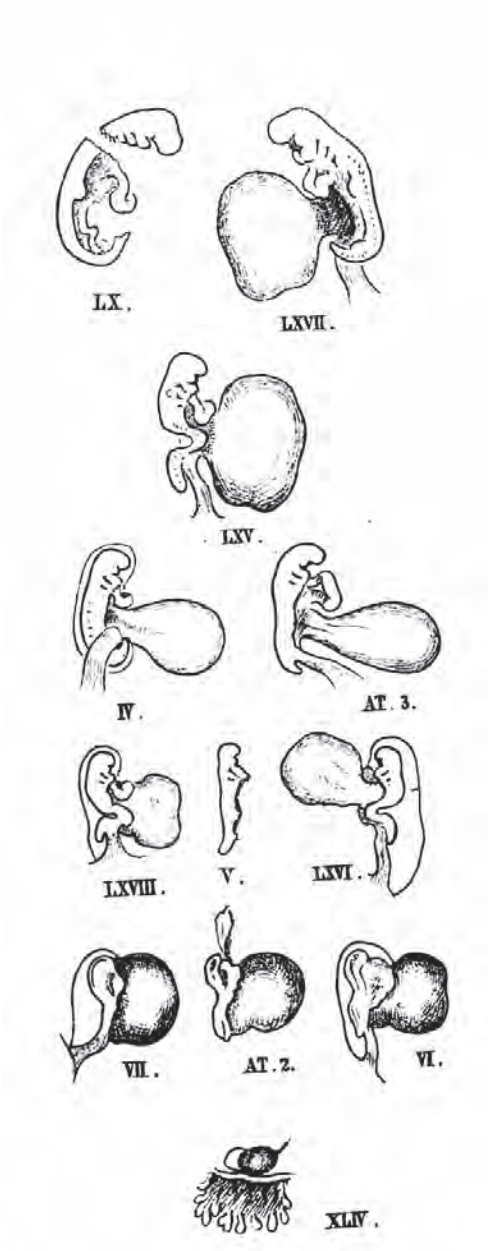

Fig. 4. A later attempt to order embryos of the first month into several morphological groups, with the most advanced specimens at the top. (From *AmE* 2, Figs. 14–25.)

remeasured, but no one could find it. Embryos described long ago by the distinguished physiologist Johannes Müller and the prominent comparative anatomist Rudolph Wagner, which Kölliker had seen no reason to question, were suspicious to His because they still had concave backs at what appeared otherwise a later stage; but while Müller's simply appeared too large for its degree of development, the peculiar facial formation and unusual limbs of Wagner's strongly suggested pathology.[58] At one stroke, two out of the five embryos from the third week of development that Kölliker had chosen only four years previously were dismissed, and another revealed as useless for quantitative work. Similar reasoning selected embryos of other stages.

His published the definitive *Normentafel* in the atlas he issued with the third part of the *Anatomie* in 1885 (Fig. 1). He had largely solved the problems of sequence and selection in the two previous installments of the work, and had assembled a consistent set of developmentally ordered specimens, from which in principle any could be taken as representative of the norms, the relations of form and size that defined each stage.[59] His chose, where possible, to include the embryos he had already described most thoroughly, but filled a few gaps with specimens from colleagues' collections. While ordering and selecting, he had worked on sharp outline drawings that he could do himself, but for the final display he took a small step back toward a softer verisimilitude. The delicate forms of the embryonic body required as artistic an execution as possible, he wrote, and so were entrusted to the closely supervised Pausch, who redrew the anatomist's old drawings from the specimens—or, when these were no longer available, from photographs.[60] Watching Pausch transfer the drawings onto the stone, His made sure that the layout of the *Normentafel* conveyed the effect of development, the sense that each succeeding image shows the same object at the next stage. He had all twenty-five numbered embryos arranged on a single plate in five rows, in developmental sequence. To make them as comparable as possible, all were shown in side view, almost all from the left. All were shown at the same magnification, and the steady increase in size, although actually representing growth rather than development, helps to convey a sense of

58. *AmE* 2: 41–43.

59. For this, the closest His came to a definition of "norm," see *AmE* 2: 2: "Mein Streben ist darauf gerichtet gewesen, die Normen menschlicher Embryonalentwicklung festzustellen, derart, dass für eine jede Stufe die zugehörigen Form- und Grössenverhältnisse bestimmt werden."

60. *AmE* 3: 6, 236.

progress. If we simply noted that His's organization followed Soemmerring's, we might take all this for granted, but plates of human embryos before and (as we shall see) since have dispensed with a strict developmental order. His chose to summarize and reinforce his work by providing the most vivid possible image of development. This convenient form was also designed to encourage embryologists staging new embryos to use the plate.

Evolutionary Controversy: Excluding an Embryo from the Canon

Until His could persuade other scientists to take up the new standards of human embryological practice that sustained the *Normentafel*, the norms would remain local to his own institute.[61] That is why he made the *Anatomie*—and why I have presented it as—a rhetorical performance, designed to be imitated in the first place by anatomists and to recruit especially gynecologists as suppliers. And that, incidentally, is how, in the near absence of unpublished relics,[62] I could reconstruct some of the practical activities that produced the *Normentafel*. It is now time to consider not just how His sought to win support, but how he won it. How, to what extent, and for how long were other people brought to use his norms? A full answer to this question would require no less than a history of human embryology since 1880—in the near total absence of a secondary literature, a major undertaking. In the rest of this paper I can only sketch some ways in which the norms were made collective. In this section I analyze a rare dispute that at an early stage blew up around His's exclusion of one embryo from the canon. The standards of analysis for which we have just seen him campaigning became the focus of debate, and since he adroitly turned this rare overt resistance to his reforms to maximum tactical advantage, the controversy also represents one means of gaining assent to them.

The extraordinary case began when, describing an embryo in mid-1875, the Göttingen anatomist Wilhelm Krause (Fig. 5) propelled it straight into the most acrimonious phase of the feud between His and Ernst Haeckel over how to do embryology and how to communicate it to

61. For norms as essentially collective, see Jacques Maily, *La normalisation* (Paris: Dunod, 1946), p. 16.

62. The bulk of His's papers appears to have been lost from the Sudhoff Institute in Leipzig during or following World War II: Dr Gottfried Zirnstein, personal communication. The Universitätsbibliothek Basel holds a small collection of manuscripts.

Fig. 5. A rare photograph of Wilhelm Krause, presented by him in March 1886 "as a memento to Prof. [Anton] Dohrn," director of the Naples Zoological Station. (Courtesy of the Archives of the Stazione Zoologica di Napoli.)

the public.[63] There were various bones of contention and several disciplinary and wider political dimensions to the dispute. Most importantly, His insisted on an anatomist's right to take a physiological approach to embryology without being encumbered by the comparative considerations that for the zoologist and evolutionary morphologist were paramount. And by objecting to Haeckel's speculative airing of the most controversial questions in front of general audiences, His joined a chorus

63. On Haeckel and various aspects of the dispute, see Stephen Jay Gould, *Ontogeny and Phylogeny* (Cambridge: Belknap Press of Harvard University Press, 1977), pp. 186–202; Dietrich von Engelhardt, "Polemik und Kontroversen um Haeckel," *Medizinhistorisches*

of professors, from Emil du Bois-Reymond down, who saw this as threatening the freedom of science in the new Prusso-German state.[64] Here we are concerned more narrowly with the protagonists' views on the similarity or dissimilarity of vertebrate embryos. The evolutionary evangelist Haeckel claimed that all vertebrates were essentially identical for the first month of embryonic life, which was proof of their common descent. His did not oppose the theory of evolution, only Haeckel's version of it: as a specialist in vertebrate embryology, he insisted that the more skilled an observer, the sooner even the earliest embryos could be distinguished—that ultimately it would be possible to differentiate not just species, but even sex and individual characters. Haeckel in the autumn of 1874 was using the schematic figures in his *Anthropogenie* (Evolution of man) to demonstrate the gospel of evolutionary progress to wide audiences; His countered a few months later with "exact" drawings highlighting the differences that would be amplified to give a pig a large snout or humans large brains, even cutting out and weighing the paper in an attempt to quantify the "specific physiognomies" of human, pig, deer, hamster, rabbit, and chick embryos. His went so far as to accuse his Jena neighbor, in a misguided attempt to bolster his evolutionary doctrine, of faking illustrations to make vertebrate embryos appear more similar than they really were, and of presenting pictures of early human embryos that he had simply invented. By so trifling with scientific truth, His charged, Haeckel had "relinquished the right to count as an equal in the company of serious researchers."[65]

His took particular exception to three figures of human embryos: one of a stage earlier than had ever been seen, and two depicting a prominent free allantois (Fig. 6B). This was a structure shaped like a sausage

Journal, 1980, *15:* 284–304; Reinhard Gursch, *Die Illustrationen Ernst Haeckels zur Abstammungs- und Entwicklungsgeschichte: Diskussion im wissenschaftlichen und nichtwissenschaftlichen Schrifttum* (Frankfurt am Main: Peter D. Lang, 1981); Erika Krauße, *Ernst Haeckel* (Leipzig: B.G. Teubner, 1984); Paul Weindling, "Ernst Haeckel, Darwinismus and the Secularization of Nature," in *History, Humanity and Evolution: Essays for John C. Greene,* ed. James R. Moore (Cambridge: Cambridge University Press, 1989), pp. 311–27; Mario Di Gregorio, "Entre Méphistophélès et Luther: Ernst Haeckel et la réforme de l'univers," in *Darwinisme et société,* ed. Patrick Tort (Paris: Presses Universitaires de France, 1992), pp. 237–83; idem, "A Wolf in Sheep's Clothing: Carl Gegenbaur, Ernst Haeckel, the Vertebral Theory of the Skull, and the Survival of Richard Owen," *J. Hist. Biol.,* 1995, *28:* 247–80; and Nyhart, *Biology* (n. 11). See also the literature on the related British controversy over the hippocampus minor—most recently, Adrian Desmond, *Huxley,* 2 vols. (London: Michael Joseph, 1994–97), vol. 1, *The Devil's Disciple,* pp. 240, 295; and Nicolaas A. Rupke, *Richard Owen: Victorian Naturalist* (New Haven: Yale University Press, 1994).

64. See esp. Keith M. Anderton, "The Limits of Science: A Social, Political, and Moral Agenda for Epistemology in Nineteenth-Century Germany" (Ph.D. diss., Harvard University, 1993).

65. Haeckel, *Anthropogenie* (n.12); Wilhelm His, *Unsere Körperform und das physiologische Problem ihrer Entstehung: Briefe an einen befreundeten Naturforscher* (Leipzig: F. C. W. Vogel, 1874; preface dated January 1875), p. 171.

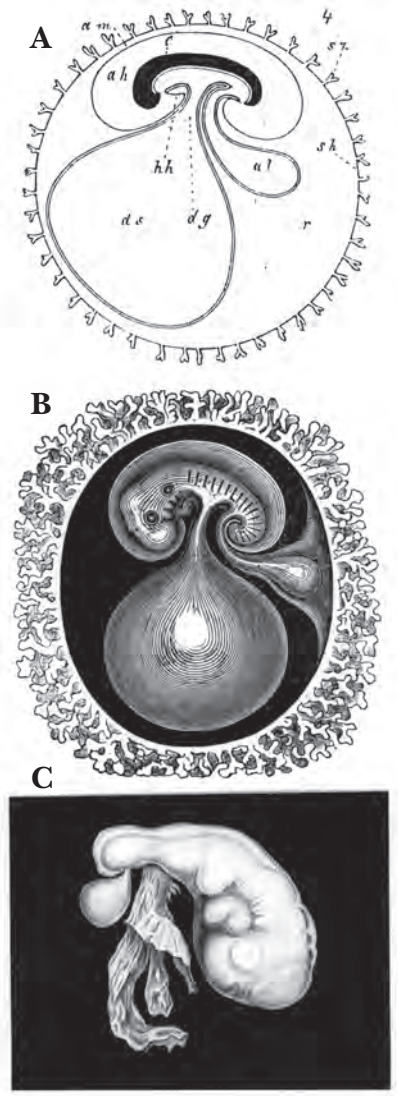

Fig. 6. (A) One of Kölliker's set of schematic figures showing development of the embryonic membranes. Posterior to the yolk sac (*ds*) is shown a free allantois (*al*), growing out toward the chorion (serous membrane, *sh*). (From Albert Kölliker, *Entwickelungsgeschichte des Menschen und der höheren Thiere* [Leipzig: Wilhelm Engelmann, 1861], Fig. 47.4 [and reused in the 1876 ed.]; by permission of the Syndics of Cambridge University Library.) (B) One of Haeckel's sketches of a human embryo with a large yolk sac and smaller free allantois. (From Ernst Haeckel, *Anthropogenie, oder Entwickelungsgeschichte des Menschen: Gemeinverständliche wissenschaftliche Vorträge über die Grundzüge der menschlichen Keimes- und Stammes- Geschichte* [Leipzig: Wilhelm Engelmann, 1874], Fig. 82; courtesy of the Wellcome Institute Library.) (C) The first published drawing of Krause's embryo with a free allantois next to remains of the yolk sac (in which [unlike the other two illustrations] anterior is to the right). (From Wilhelm Krause, "Ueber die Allantois des Menschen," *AAP,* 1875, pp. 215–16; by permission of the Syndics of Cambridge University Library.)

skin, known in birds and some mammals to grow out of the hindgut to form a bridge between the embryo proper and the chorion, which was crucial to embryonic nutrition; in the latter it made a major contribution to the umbilical cord. But, His declared, the allantois was "in humans well known never to be visible in the form of a vesicle."[66] Actually, while Kölliker's textbook was skeptical of the many claims to have seen a free allantois in humans, he implied that this was because no one had found an embryo of just the stage when the allantois had formed but was still free (Fig. 6A).[67] While Haeckel made the "not seen" but fully expected into a drawing, His made it into the "never visible." Associate professor Krause now saw an opportunity to make some capital out of a specimen he had had in his collection for some time. In a short note, "On the Allantois of Man," he described an embryo of 8 mm that he estimated as being toward the end of the fourth week of pregnancy (Fig. 6C): "One can recognize in the perfectly true to nature . . . figure the surrounding amnion, the budding upper and lower extremities, three gill arches, the heart, the torn yolk sac, and the allantois."[68] Haeckel exulted, and in a

66. Ibid., p. 170.

67. See Albert Kölliker, *Entwickelungsgeschichte des Menschen und der höheren Thiere* (Leipzig: Wilhelm Engelmann, 1861), p. 124. See also Samuel L. Schenk, *Lehrbuch der vergleichenden Embryologie der Wirbelthiere* (Vienna: Braumüller, 1874), pp. 64, 179. On the earlier history of the allantois, a topic that His called "the most discussed in the whole of human embryology" (*AmE* 1: 170), see especially Arthur W. Meyer, "The Elusive Human Allantois in Older Literature," in *Science, Medicine and History: Essays on the Evolution of Scientific Thought and Medical Practice Written in Honour of Charles Singer,* ed. E. Ashworth Underwood, 2 vols. (London: Oxford University Press, 1953), 1: 510–20; Howard B. Adelmann, *Marcello Malpighi and the Evolution of Embryology,* 5 vols. (Ithaca: Cornell University Press; London: Oxford University Press, 1966), 4: 1550–1602; and James D. Boyd and William J. Hamilton, *The Human Placenta* (Cambridge: Heffer, 1970), pp. 1–19. Meyer seems not to have completed the projected second part of his history of the human allantois, but he does here refer briefly to the Krause controversy, suggesting that "its final resolution had to await the invention of new technical methods" ("Elusive Human Allantois" [n. 67], p. 520). My analysis shows that the dispute was as much over, as resolved by, the new methods; and that Krause's embryo was discredited without actually being subjected to them.

68. Wilhelm Krause, "Ueber die Allantois des Menschen," *AAP,* 1875, pp. 215–16. In 1860 Krause (1833–1910) had moved to Göttingen as associate professor with responsibility for pathological anatomy. He apparently took the job as a stepping-stone to an anatomical chair, but he ended up representing a subject in which he was not interested and the clinicians considered him incompetent, and in 1876 was finally removed from the post. However, even his fiercest detractors in the faculty acknowledged the quality and quantity of his work in normal anatomy. He had published widely, including an anatomy of the rabbit, and was an authority on nerve endings, especially motor end-plates, as well as a popular and effective teacher. He was therefore moved sideways to a probably far more congenial position as an associate professor of (normal) anatomy. He was no embryological specialist, but as an anatomist, embryology was within his general sphere of expertise. See

polemic against His he paraded the embryo as proving the power of evolutionary "deductions."[69]

Haeckel sent the revised edition of his *Anthropogenie*, featuring Krause's embryo alongside the original sketch, to his journalist friend Carus Sterne, who in 1877 duly gave it a rave review in *Kosmos*, the Darwinists' new party paper. Frustrated, as he tried to boost the magazine's circulation, with the "boring" and "indigestible" philosophizing of his coeditor Otto Caspari, Sterne wrote "amusing and racy" articles to make readers feel they were getting "their money's worth."[70] Picking up Haeckel's presentation of the Krause case, Sterne's unashamedly partisan review compared the zoologist to Alexander the Great—both had dared and won—and turned the liberal His into a bigoted and carping inquisitor. Haeckel had called on "the genius of comparative anatomy" "to make the never-before-seen show itself in the mirror of science"; the result was "great excitement among the waiting enemies," who thought they had caught him out, and from "Prof. His, chairman of the holy secret court [*Vehme*]," a "criminal charge":

> Fortuna, however, does not abandon the courageous. At the time of greatest need she sends Prof. Krause in Göttingen the never-seen to inspect, and behold, it appears in exactly the form that Haeckel had sketched. The accusers now take their stand on an old paragraph of the holy penal code, in which is written that prophecy [*Wahrsagen*, literally "telling the truth"] is forbidden.

[Professor Richard J. Anderson of Galway], "Professor Wilhelm Krause, Berlin," *Brit. Med. J.,* 1910, *1:* 550; "Prof. Dr. Wilhelm Krause†," *Internationale Monatsschrift für Anatomie und Physiologie,* 1910, *27:* frontispiece (which names Anderson as author of the *BMJ* obituary); and Paul Bartels, "Wilhelm Krauses Schriften," *AA,* 1911, *39:* 266–72. On the troubles at Göttingen, see Johannes Alfers, *Die pathologische Anatomie in Göttingen unter Förster, Beckmann, W. Krause und Ponfick (1852–1878)* (Göttingen: Vandenhoeck & Ruprecht, 1935); and for discussion of Krause's personality and his move to Göttingen, see Hans-Heinz Eulner and Hermann Hoepke, eds., *Georg Meissners Briefe an Jacob Henle 1855–1878* (Göttingen: Vandenhoeck & Ruprecht, 1975), pp. 48–49, 79, 82–83. Robert Koch carried out a prize-winning anatomical study under Krause's direction; see Thomas D. Brock, *Robert Koch: A Life in Medicine and Bacteriology* (Madison, Wisc.: Science Tech Publishers, 1988), p. 11.

69. Ernst Haeckel, *Ziele und Wege der heutigen Entwickelungsgeschichte* (Jena: Hermann Dufft, 1875), pp. 36–37.

70. Carus Sterne to Ernst Haeckel, 13 September 1877, Best. A, Abt. 1, Ernst-Haeckel-Haus, Jena. For the gift of the book, see Sterne to Haeckel, 5 December 1876, ibid. On Sterne, a pseudonym of Ernst Krause (unrelated to Wilhelm), see Andreas Daum, "Naturwissenschaftlicher Journalismus im Dienst der darwinistischen Weltanschauung: Ernst Krause alias Carus Sterne, Ernst Haeckel und die Zeitschrift *Kosmos*. Eine Fallstudie zum späten 19. Jahrhundert," *Mauritiana (Altenburg),* 1995, *15:* 227–45.

> However, it appears that this is a slip of the pen, and that in science it is rather *not telling the truth* [*Unwahrsagen*] that produces a bad reputation.[71]

It might be true in everyday life that fortune favors fools, Sterne mocked, but not in the history of science, where only they have luck and success who have really earned it.

Meanwhile, several unimpressed embryologists were voicing concern that they could not place Krause's specimen in developmental series of the known human embryos. Kölliker held that an 8 mm embryo from the fourth week of pregnancy with limb anlagen, head curvature, "gill slits," eyes, and a developed heart could not still lack an umbilical cord, which should develop *from* the allantois, when three-week-old embryos were known already to have one. Until convinced otherwise, he would regard what Krause had taken to be the allantois as in fact the yolk sac, and what Krause called the yolk sac, but was in his view too large, as actually the umbilical cord with rags of amnion attached. When Krause rejected this proposal as "unanatomical," and insisted that one could not take age estimates so exactly, Kölliker suggested that the specimen was pathological.[72] Neither Ahlfeld, the Kiel physiologist Victor Hensen, nor the Graz professor of histology and embryology Victor von Ebner was able to make Krause's embryo fit with other known specimens, or specifically with the new human embryos they described.[73] Haeckel's faith in the embryo was looking rash, to say the least,[74] but the field of human embryology was still too open and too little standardized for any specimen to be excluded from the discussion.

71. "K.," *Kosmos,* 1877, *1:* 275–76, discussing Ernst Haeckel, *Anthropogenie*, 3d ed. (Leipzig: Wilhelm Engelmann, 1877), pp. 307–8.

72. Kölliker, *Entwicklungsgeschichte* (n. 57), 1: 306–7; 2: 1013; Wilhelm Krause, "Ueber die Allantois des Menschen," *AAP,* 1876, pp. 204–7.

73. Friedrich Ahlfeld, in "Die Allantois des Menschen und ihr Verhältniss zur Nabelschnur," *Archiv für Gynäkologie,* 1876, *10:* 81–117, was, however, much more disposed than Kölliker to accept older descriptions of embryos with a free allantois. See also Victor Hensen, "Beitrag zur Morphologie der Körperform und des Gehirns des menschlichen Embryos," *AAP,* 1877, pp. 1–8; Victor v. Ebner, "Ueber die erste Anlage der Allantois beim Menschen. Vortrag, gehalten in der Versammlung vom 28. Mai 1877," *Mittheilungen des Vereins der Aerzte in Steiermark,* 1877, pp. 28–29.

74. Carl Semper, the Würzburg zoologist campaigning against "Haeckelismus" in zoology, mobilized Kölliker's objection in order to criticize Haeckel's continued deployment of Krause's embryo in the third edition of the *Anthropogenie.* Haeckel had used the new edition of Kölliker's textbook, but selectively ignored his reservations about this embryo: another example of picking and choosing facts to suit theories. See *Offener Brief an Herrn Prof. Haeckel in Jena* (Hamburg: W. Mauke's Söhne, 1877), pp. 27–28.

The *Letters on the Form of Our Body,* in which His had accused Haeckel of inventing the free human allantois, was his only attempt to convert the wider reading public to his views, and he apparently commented on the Krause embryo only to fellow specialists. This opposition to airing undecided scientific questions before the court of public opinion let Haeckel and his cronies get the better of the exchange—a rare victory at a time when Haeckel's scientific authority was taking a beating. Instead, His had written to Krause privately telling him that he suspected his embryo was not human, and asking for more information about where it came from,[75] and in 1878 he embarked on an unprecedentedly systematic study of human embryos. The later phase of His's involvement in the history of Krause's embryo began when he announced to the Anatomical Section of the Congress of German Naturalists and Physicians in September 1879 that it was the embryo of a bird.[76] By this time the Haeckelian controversies had simmered down, and Haeckel played no further direct role in the matter. We can at present only conjecture as to the strength of the relationship between His's initial spat with Haeckel and his later actions, but at its strongest, it is possible that by investing the degrees of similarity and difference between vertebrate embryos with controversy, Haeckel actually goaded His into creating a new kind of human embryology—one that, no longer an afterthought in textbooks concentrating on the chick and domestic mammals, could, if it chose, deal with comparative questions from a strong and independent position. Certainly, the *Anatomie menschlicher Embryonen* stood implicitly for the specificity of human development, the independence of anatomy from zoology, and—an expensive monograph for fellow specialists—comprehensive analysis with the latest techniques, which only a specialist could achieve. Equally clearly, His directed his reforms not only to taking the study of human embryos out of the hands of clinicians, but also to making it inaccessible to those he dismissed as "*entwicklungsgeschichtliche* [embryological or evolutionary] amateurs."[77]

In the first part of the *Anatomie* His cited Kölliker's main reason, that much younger human embryos were known with absolute certainty to be attached to the chorion by a stalk, as grounds for refusing to entertain Krause's claim, especially on the basis of a simple profile drawing. He considered Kölliker's original suggestion, that the "allantois" was the yolk sac, by no means implausible; Krause would have the right to refute it so

75. His, "Kritik" (n. 43), p. 407.

76. His, "Menschl. Embryonen" (n. 35). Note that this claim was not made in one of the widely reported general sessions, but among anatomists.

77. *AmE* 1: 68.

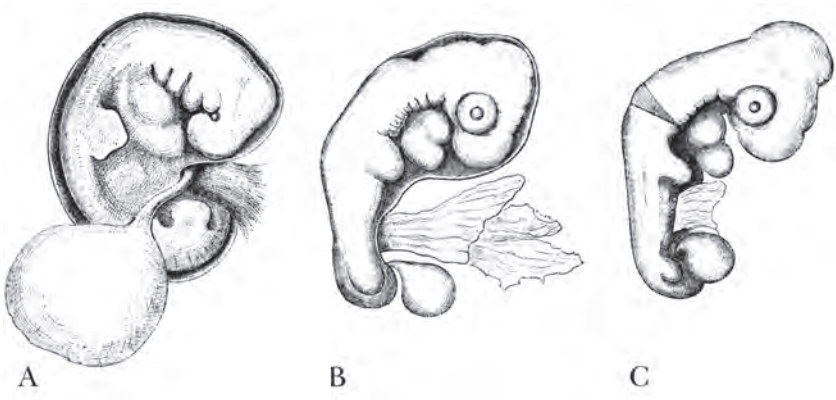

Fig. 7. His's drawings comparing (A) human embryo B, (B) Krause's embryo, and (C) a chick embryo. (From *AmE* 1: Figs. 5–7.)

vehemently only if he cut sections to show the deeper insertion of the "allantois." But the Leipzig anatomist bet on another possible confusion: a critical comparison of Krause's figures with "good illustrations" of human embryos of the same stage revealed a series of major differences, in all of which, he said, Krause's embryo resembled those of birds (Fig. 7). The midbrain was too small to be human, the diameter of the eye about three times too large, the pharyngeal arches too short, there was no trace of the liver (which should by this stage have been a noticeable swelling), and the posterior end of the body was a short stump instead of a substantial forward-curling structure—indeed, the whole body was too little curved. Since all three of Krause's drawings agreed, His took them to be faithful. The problem must lie in the embryo. He had elicited in a letter from Krause the information that it came from a physician friend: "The error may have been caused by a chance confusion, but it may rest on an actual deception [*Mystification*]. On that, of course, only Krause himself can shed light, after he has first consulted with his source."[78] His proceeded to develop a new hypothesis according to which in humans the embryo never separated from the chorion, but remained linked to it through a "belly stalk"; the relatively tiny allantois at no stage projected as a free vesicle into the chorionic cavity, but grew as a duct along the already-present connection: a free allantois was not just "not visible," it never existed.[79] What concerns us here is how His worked

78. *AmE* 1: 68–72, quotations on pp. 70, 72.

79. *AmE* 1: 169–73; 3: 222–26. Kölliker stuck to his guns through the early 1880s—see Albert Kölliker, *Grundriss der Entwickelungsgeschichte des Menschen und der höheren Tiere,* 2d ed. (Leipzig: Wilhelm Engelmann, 1884), p. 140—but His's view came widely to be accepted as a human, or more generally primate, peculiarity.

to shift the burden of authenticating the embryo onto the Göttingen anatomist.

For Krause put up a robust defense, in which he rejected or ignored every single one of His's reforms. He failed to respond to the invitation to provide more information on provenance. He refused, until he gained agreement on external morphology, not only to section the embryo, but even to remove the amnion or let it travel; all were too risky, he claimed. He made a probably not very persuasive song and dance about how, though the allantois had been shown faithfully from the start, the artists employed by the journals had in other respects misdrawn his figures. He released new drawings, authenticated as faithful reproductions by the Göttingen zoologist and editor Ernst Ehlers, and used these to contest or dismiss as trivial all of the points on which His reckoned his embryo birdlike—even, in his turn, presenting drawings of his embryo, another human embryo, and a couple of chick embryos side by side. The major revision of his previous interpretation was to claim that what he had originally labeled as a huge chicklike "eye" was in fact the dome of the cerebrum. To solve the most worrying problem, that much younger embryos had been described with fully formed umbilical cords, Krause appealed to the ever-present concern that aborted embryos might have been aborted precisely because they were pathological: to explain these cases he assumed that a disturbance of the yolk circulation led to formation of the allantois too early to compensate for that hydraulic imbalance, and that as a consequence the embryos died. Human embryos could be considered completely normal only if they matched his own, one of Wagner's, and regularly developing animal embryos. Early adhesion of an embryo with the chorion—the very basis of His's theory of "belly stalk" formation—was abnormal.[80]

Krause's fuss about the drawings appears unconvincing, but he was still in the fight. Most significantly, while other embryologists remained skeptical of the embryo, even after reading the *Anatomie* the embryologically active and critical gynecologist Ahlfeld, the elderly Freiburg anatomist Alexander Ecker, and the British embryological prodigy Francis

80. Wilhelm Krause, "Über einen frühzeitigen menschlichen Embryo," *Zoologischer Anzeiger,* 1880, *3:* 283–84; idem, "Über zwei frühzeitige menschliche Embryonen," *Zeitschrift für wissenschaftliche Zoologie,* 1880, *35:* 130–40. Krause did not oppose sectioning per se—like dozens of scientists in the 1870s, he had himself designed a microtome—but for him, as for many others whom His was trying to persuade, sectioning a specimen that could easily be replaced was a completely different matter from trusting an irreplaceable object to the knife. See Wilhelm Krause, "Der ventriculus terminalis des Rückenmarks," *Archiv für mikroskopische Anatomie,* 1875, *11:* 216–30, on pp. 227–29; idem, "Ueber Mikrotome," ibid., 1877, *13:* 180.

Balfour all continued to suggest various ways in which it might represent a human abnormality.[81] These responses are the most surprising and instructive in the whole dispute. Perhaps these men were reluctant to associate themselves with a scandalous suggestion; their various interpretations provided less embarrassing ways of discrediting the embryo. But no specialist either leapt to endorse His's view or refused to discuss the specimen until it was more thoroughly documented. How could he establish norms of human development while a professor of anatomy continued to defend as perfectly normal a specimen that some said was a human abnormality but that he reckoned was not even a mammal? This is the measure of how far His still had to push embryologists to accept his reforms, but it also gave him a golden opportunity to drive them home.

In late 1880, His replied to Krause with an article that he incorporated in part into the second installment of the *Anatomie.* As the title, "On the Criticism of Younger Human Embryos," implied, he used the opportunity of lecturing Krause to reassert the new standards of analysis. First, he demanded again that Krause provide information on the provenance and original condition of the embryo. For His, data such as gynecological history and whether or not Krause had received the embryo already opened, were not merely incidental:

> In human embryology we still find ourselves at the stage where we proceed case by case, where we must check usable objects individually and compare them to each other. Under these circumstances it is imperative formally to legalize every new document properly before introducing it into the discussion. This is especially so when the document involved, like yours, flatly contradicts every other including the best authenticated.[82]

Second, His disputed Krause's defense, upholding the original identification of the "eye" and making various new measurements, but he

81. Friedrich Ahlfeld, review of Krause, "Über zwei frühzeitige menschliche Embryonen," *Centralblatt für Gynäkologie,* 1880, *4:* 603; Alexander Ecker, "Beiträge zur Kenntniss der äusseren Formen jüngster menschlicher Embryonen," *AAP,* 1880, pp. 403–6; Francis M. Balfour, *A Treatise on Comparative Embryology,* 2 vols. (London: Macmillan, 1880–81), 2: 224–26. In an earlier review of *AmE* 1, however, Ahlfeld had stated that his colleague had proven Krause's embryo to be a bird; see Friedrich Ahlfeld, review of *AmE* 1, *Centralblatt für Gynäkologie,* 1880, *4:* 223–25, on p. 224; and also Ahlfeld, review of Krause, "Über einen frühzeitigen menschlichen Embryo," ibid., p. 367. For Krause's rebuttal, see "Über die Allantois des Menschen," ibid., 1881, *5:* 1–2. Friedrich Merkel also implied agreement with His: see Friedrich Merkel, "Entwickelungsgeschichte," *Jahresbericht über die Leistungen und Fortschritte in der gesammten Medicin* (hereafter *JLFM*), 1881, *15* (1): 78–105, on p. 94.

82. His, "Kritik" (n. 43), p. 410.

insisted that only the removal of the amnion and the sectioning of at least the head could resolve the matter decisively. He turned, third, to the crucial issue of comparative judgment, of how embryos should be ordered and selected. Krause's parting shot was a gift. He had explained his embryo's lacking a connection to the chorion by asserting that all such cases were pathological. "It is a brave advance into enemy territory that you have undertaken there," His mocked:

> Going past all obstructing positions you place your embryo, in spite of its lacking legitimation to this day, in the middle of the dominating area. . . . The value as scientific evidence of the human embryos known until now that are younger than yours and nevertheless joined to the chorion is annulled, and henceforth the following, until now largely well accredited, company is to be dismissed.[83]

He listed five of his own embryos, two each of Coste and Thomson, Müller's embryo, and one that Ecker had just described, and discussed a couple of other cases:

> If I draw the correct conclusions from your statements, then there is just nothing else for it but to break with the previous human embryology, and beginning with yours as the youngest normal human embryo known until now to make a new start. . . . Whether many specialists will follow you on your march and protect your position, time must tell.[84]

His expended so much effort on Krause's embryo because it threatened the whole basis on which he was setting up norms: critical comparison of embryos among themselves. When for a given stage of development embryologists had several representatives agreeing in their particulars, he argued, they could hardly be in doubt about the norm for that stage. In the *Anatomie* he had already sifted the existing early material and concluded that at least for the second half of the first month they had a fairly continuous series of well-observed and normal human embryos. Krause showed that this argument was far from logically compelling: perhaps the vast majority of aborted embryos showed characteristic abnormalities responsible for their abortion. This was a risk His had to take, but he sought to minimize the vulnerability of his norms to "uncritical or . . . overcritical gusts of wind" by insisting on extremely thorough analyses.[85] Had Krause got away with "saving" his embryo by "throwing"

83. Ibid., p. 413.

84. Ibid., p. 414. His had not yet rejected Müller's embryo, and his only objection to Coste's most famous specimen was that its exact magnification was not known.

85. Ibid.

previously well regarded material "overboard," then His's whole project would have been doomed.[86]

Krause nevertheless fought on through 1881, continuing to dispute measurements and observations while giving no more information on provenance and refusing to budge on means of analysis.[87] It is surely unlikely that anatomists would ever have accepted Krause's specimen as a normal human embryo on the basis of his defense, but in 1881 (as in 1880) none was actually prepared to side with His. Crucial to the course of the debate, and to its closure in 1882, was the way in which new information was made available to, or withheld from, Krause's critics. The key resource was control of the specimen. As long as the embryo was in his hands alone, Krause could regulate what was made public and how. One scientist after another could suggest interpretations, but Krause would use new information to scotch some and contest others. The issue was stalled. He could not stem the criticism, but then neither, it seems, could anyone else decisively discredit the embryo. His's questions were directed toward producing more information on which to work. He also insisted that the embryo could be sent on the train or brought to a conference so that others would be freed from reliance on Krause's drawings. His had proposed in vain that Krause bring the specimen to the German Anthropological Society Congress in Berlin in the summer of 1880, but because Krause would not let the embryo travel, the others had been limited to arguing over his drawings, while he made the most of the vicissitudes of micrography and reproduction for printing. Though Krause may have had an interest in prolonging the dispute in the hope of avoiding a crushingly negative verdict, there is no reason to believe that he was deliberately obstructive: within his understanding of what it was safe to do with the embryo, he appears to have behaved openly and confidently. The embryo could not go to the embryologists, but he had invited them to Göttingen to see it. His had declared himself willing to participate in a conference at which Krause's colleagues would "sit in judgment on your embryo," provided that the experts were allowed to deal with it as should seem necessary for "a strict scientific assessment of its particularities," and specifically that after photography Krause permit a disinterested party to cut sections.[88]

86. Ibid., p. 420.

87. Wilhelm Krause, "Über die Allantois des Menschen," *Zoologischer Anzeiger,* 1881, *4:* 185; idem, "Über die Allantois des Menschen," *Zeitschrift für wissenschaftliche Zoologie,* 1881, *36:* 175–79. Gustav Born (Breslau) gave a fairly even-handed summary of these exchanges, but praised His's "Kritik"; see "Entwicklungsgeschichte: Säuger," *Jahresbericht über die Fortschritte der Anatomie und Physiologie,* 1882, *10* (1): 454–62, on pp. 458–59.

88. His, "Kritik" (n. 43), p. 412. See also Krause, "Embryonen" (n. 80), p. 133.

An opportunity finally came at the celebration in Göttingen on 4 April 1882 of the fiftieth anniversary of the award of a medical doctorate to Jacob Henle, the grand old man of German anatomy. Henle's prestige and the preparations of his students and colleagues made this one of the most lavish and memorable occasions of its kind. Old students, friends, and official delegations descended on the town; honors and congratulations flooded in; the celebrants ate, drank, and regaled each other with speeches.[89] And, unmentioned in reports of the festivities, embryologically interested anatomists used some spare time finally to view what Kölliker called "the famous object," which in Krause's absence Ehlers had been empowered to show them. Krause appears initially to have made the arrangement with Wilhelm Waldeyer from Strassburg, but Kölliker and the Breslau professor of anatomy, Carl Hasse, certainly saw it too, and Henle's son-in-law Friedrich Merkel from Rostock was also present. (His was not: he had not been a student of Henle, and Leipzig was represented by his anatomist colleague Wilhelm Braune and the physiologist Carl Ludwig.)[90]

Unless new documents come to light, many questions about the dénouement of the Krause affair will remain unanswerable. Why could he not be present? With what expectations did the anatomists approach the microscope? We do know that they were not permitted to touch the specimen. Kölliker and Hasse, with Waldeyer's tacit approval, were nevertheless prepared in open letters to His to declare it a bird. Faces were saved by focusing on various microscopical features that had not been apparent in Krause's drawings. The anatomists wrote that the huge size

89. *Frankfurter Zeitung,* 8 April 1882, Abendblatt, p. 2; *Beiträge zur Anatomie und Embryologie als Festgabe: Jacob Henle zum 4. April 1882 dargebracht von seinen Schülern* (Bonn: Max Cohen & Sohn, 1882); Friedrich Merkel, *Jacob Henle: Ein deutsches Gelehrtenleben. Nach Aufzeichnungen und Erinnerungen erzählt* (Braunschweig: F. Vieweg & Sohn, 1891), pp. 349–52. On the exceptional success of the celebration, see Waldeyer to Henle, 3 May 1882 and 29 April 1883, in Hermann Hoepke, ed., "Wilhelm Waldeyer. Briefe an Jakob Henle 1863–1885. Dritter Teil (1881–1885)," *Ruperto Carola,* 1976, *57:* 43–54, on pp. 45, 47 (thanks to Paul Weindling for a copy of this article). Controversies over "tailed people," with an embryological dimension that His addressed in *AmE* 1: 89–96, were widely reported in these years, but I have yet to find newspaper references to the more esoteric dispute over the allantois. On those controversies, see Andrew Zimmerman, "Anthropology and the Place of Knowledge in Imperial Berlin" (Ph.D. diss., University of California, San Diego, 1998), pp. 140–47.

90. Albert Kölliker, "Der W. Krause'sche menschliche Embryo mit einer Allantois: Ein Schreiben an Hrn. Prof. His," *AAP,* 1882, pp. 109–10; Carl Hasse, "Erklärung über den Krause'schen Embryo," ibid., p. 203. For Merkel's presence during the viewing and his light sarcasm expressing exasperation with Krause, see Friedrich Merkel, "Entwickelungsgeschichte," *JLFM,* 1882, *16* (1): 94–118, on p. 103; and for the Leipzig representatives, Merkel, *Henle* (n. 89), p. 350.

of the yolk sac implied by its remains and the massive vessels it contained persuaded them that what Krause had described was a bird. That it was a chick, they could not say; it might just as well have been a duck, a goose—or a turkey.[91]

These declarations were authoritative enough to close the public debate. But Krause did not just throw in the towel. He appears to have tackled Waldeyer before Kölliker's letter appeared in print, and not to have been satisfied with the reply. On 23 May, Waldeyer reported to Ehlers: "I have written to W. Krause; he seems not yet to want to give in and so we shall probably have to reach for the final argument, dissection [*Zerlegung*]; it would be best if K. would decide on this himself."[92] As it had in Kölliker's statement, dissecting, not necessarily sectioning, the embryo appears here as a last resort, not the routine means of investigation that His claimed microtomy should be. Krause now privately conceded that as soon as the embryo was sectioned, its nature would be very easy to determine, but he was still reluctant to allow it because then the points that had been disputed would, he reckoned, become undecidable.[93] It was probably around this time that he took the specimen to nearby Marburg in an unsuccessful attempt to win over the anatomist and embryologist Nathaniel Lieberkühn.[94] Krause may never have been fully reconciled to the negative verdicts, but he could no longer afford to

91. Kölliker, "Der W. Krause'sche menschliche Embryo" (n. 90); Hasse, "Erklärung" (n. 90).

92. Waldeyer to Ehlers, 13 May 1882 (and see also the letter of 23 April 1882), Ehlers Papers, Niedersächsische Staats- und Universitätsbibliothek Göttingen.

93. "Sobald der Embryo zerschnitten wird, ist ja seine Natur sehr leicht festzustellen. Aber dann lassen sich obige Punkte . . . nicht wie bisher mehr entscheiden" (Krause to [unidentified] Herr College, 29 May 1882, Archiv, Autographen K9, Germanisches Nationalmuseum Nuremberg).

94. The memoirs of the anatomist Hans Strahl, then a young *Privatdozent* in Lieberkühn's institute, include an ironic recollection of Krause's Marburg demonstration, which Strahl dates "about the end of 1882"; it is certainly likely that it followed the Göttingen viewing, and so the Marburg anatomists will have been inclined to disbelieve Krause's claim. In preparation for the visit, Strahl reported, Lieberkühn had the staff collect together the rather wide range of vertebrate embryos of that stage which they had to hand, and compare them to Krause's illustrations. They excluded the possibility that his embryo was mammalian or reptilian, but found it to agree "quite well, perhaps not perfectly," with the forms of a chick embryo; however, it resembled one of the canary embryos which *Privatdozent* Emil Gasser had collected "like two peas in a pod" (literally, "as one egg to the other"). When Krause arrived, Lieberkühn, his prosector Richard Wagner, Gasser, and Strahl all assembled, and "the precious specimen was unpacked with the greatest conceivable care and inspected by everyone under the magnifying glass." When Lieberkühn declared his agreement with His, Krause became very agitated and "sought to counter his objections. Then Gasser came over with a dish and a very wily face . . . and presented his embryo. Krause was very affected by the absolute identity of the object with his own, and attempted to identify

challenge them. The affair does not appear, however, to have had serious consequences for him. The subsequent fate of the embryo is unknown.[95]

Controversy arising out of the embryo pictures in Haeckel's *Anthropogenie* raged until the end of his career, but he did not comment on Krause's embryo in the written record after 1877. This dispute had taken on a life of its own, largely independent of Haeckel's opportunistic seizing on the specimen.[96] I have yet to find evidence that the events at the Henle celebration were orchestrated in order to discredit one of Haeckel's prize exhibits by anatomists hostile to his brand of Darwinism—as Henle, Kölliker, Waldeyer, Merkel, and, of course, His all were—or that the verdict was then exploited against him.[97] Ironically, Kollmann, attempting to conciliate between the views of Haeckel and His, cited the confusion over Krause's embryo as *supporting* Haeckel's position:

> Who does not remember that only a few years ago the embryo of a bird was declared and described as that of a human being, and it took some effort to determine the error. After such an event a claim of Haeckel's . . . about the similarity of vertebrate embryos among themselves appears in another, less unfavorable light, and the bad faith of which he was accused was surely not present.[98]

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the new one as a human embryo too; whereupon Gasser intimated that he had a canary before him. In view of these facts Krause had to capitulate and went home with his glass and the embryo, which by the way was probably not even a canary but a somewhat distorted [*veränderter*] chick embryo. He never reported publicly on the Marburg visit and his experiences, however, and took nothing back. It also never came out whether the whole thing was based on an error of some kind or if Krause . . . had perhaps become the victim of a conscious deception." Strahl's memoirs are quoted in Bruno Henneberg, "Professor Hans Strahl," *AA,* 1922, *55:* 211–20, on pp. 215–16. The most parsimonious hypothesis is that the letter quoted in n. 93 was addressed to Lieberkühn and led to Krause's visit to Marburg.

95. I am not aware that Krause had a scientific-political axe to grind in the dispute, and anatomists later assisted the already blighted career of this Henle protégé. He went on to review—of all fields!—*Entwickelungsgeschichte* for Virchow and Hirsch's *Jahresberichte,* and in 1892 Waldeyer took him on as "laboratory director" in Berlin. For a hint of Krause's not being reconciled, see Wilhelm Krause, "Entwickelungsgeschichte," *JLFM,* 1888, *22* (1): 67–111, on p. 88. Report of lack of information on the fate of Krause's embryo from Prof. Gerd Steding, Institut für Anatomie, University of Göttingen, to the author, 2 September 1997.

96. Haeckel excised the reference to the embryo from the much less polemical 4th edition of the *Anthropogenie* (Leipzig: Wilhelm Engelmann, 1891). On the later controversies over the pictures, see esp. Gursch, *Illustrationen* (n. 63).

97. On anatomical politics and Darwinism, see Paul Julian Weindling, *Darwinism and Social Darwinism in Imperial Germany: The Contribution of the Cell Biologist Oscar Hertwig (1849–1922)* (Stuttgart: Gustav Fischer, 1991), pp. 195–213.

98. Julius Kollmann, "Die Anatomie menschlicher Embryonen von W. His in Leipzig," *Verhandlungen der Naturforschenden Gesellschaft in Basel,* 1890, *8:* 647–71, on p. 665. By

But Kollmann praised His fulsomely for putting the unusually difficult human embryology on a more detailed basis than that of any other mammal. The controversy over Krause's embryo was instrumental in helping him do this. The wisdom of hindsight tempted some to pronounce it "easy to see" that Krause's was not a mammalian embryo from the original illustration alone,[99] but Kollmann's point about the effort it had taken to make this so evident was not lost.

The enormous and very public exertion that was needed in order to exclude the most notorious human embryo of the age shows how hard His had to work. And if the new methods had not actually been needed, at least a specimen that failed to meet his standards of analysis had been dismissed, and the risks of casually doing a bit of human embryology on the side had been seared into the memories of anatomists for generations to come.

Anatomists Use the *Normentafel*

Having discussed in some detail how His used the Krause case to promote his reforms, and having suggested that it also reveals an important reason why he was interested in reforming human embryology, I would like now briefly to outline how anatomists adopted his norms. By taking this historical sketch up to the human *Normentafel* of 1908, I wish to show further that not only did the next generation revise these norms, the *Normentafel* design itself threatened to become unworkable. The effort that His had put into producing development ensured that human embryology flourished very much on his model, but anatomists could no longer accept his particular solution to the problems of sequence and selection.

Frank controversy over either principles or individual embryos was rare. Surely, by investing in a massive and thoroughly documented work that demonstrated unparalleled experience of human embryos, one of Germany's most powerful anatomists overwhelmed much potential opposition. Winning his wager on Krause's embryo increased His's authority still further and probably helped to frighten embryological dabblers out of the business. We should also bear in mind that he was not

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contrast, Harvard anatomist Charles Sedgwick Minot, in *Human Embryology* (New York: William Wood, 1892), p. 355, accused Haeckel of making a mistake "through hasty and unfounded speculation."

99. Jan Janošík, "Zwei junge menschliche Embryonen," *Archiv für mikroskopische Anatomie,* 1887, *30:* 559–95, on p. 579.

competing with another normative project, but seeking only to change the way scientists described human embryos and selected representative series. Yet though he was successful, embryologists took time to negotiate his reforms. Some contemporaries who quickly recognized in the *Anatomie* the most important study of human embryology since Coste, just put what His had produced into the familiar frame.[100] In textbooks, his new specimens gradually replaced older ones, but the Berlin anatomist Oscar Hertwig continued in 1888 to cite embryos that His had sought to push beyond the pale.[101] Gynecologists and other clinicians appear to have cooperated in supplying material, though some still ventured into embryology on their own account. Most controversially, Greifswald associate professor Franz von Preuschen claimed in his turn to have found a free vesicular allantois, but his considerable efforts failed to convince anatomists that he had worked according to the new standards; His judged the embryo to have been dead in the uterus so long that it was disintegrating.[102] Others continued to insist they could make a contribution; Carl Heinrich Stratz, a gynecologist in private practice, even pointed out stroppily that whatever his colleagues' failings, His had accused none of a worse error than Krause—an anatomist.[103]

It is among a younger generation of anatomists that the Göttingen meeting would truly symbolize a refounding of human embryology, and the *Anatomie* really take hold. His offered them an attractive prospect:

100. Having recognized the technical advances of the first installment of His's work over Coste's, and having praised it as "the foundation of a special anatomy of the human embryo," Ahlfeld included the many rejected embryos of his gynecological colleagues in lists assigning embryos to stages; see Ahlfeld, review of *AmE* 1 (n. 81).

101. In the condensed 1884 edition of his textbook (n. 79), the already critical Kölliker signaled the importance of His's work in the preface (p. iii), and from the 1876 edition (n. 57) he kept the Coste embryo, against which His's only objection was the lack of magnification evidence; but he excluded the Müller and Wagner embryos that His said were abnormal. Oscar Hertwig, *Lehrbuch der Entwicklungsgeschichte des Menschen und der Wirbelthiere,* 2d ed. (Jena: Gustav Fischer, 1888), pp. 177–202, still listed the Beigel and Löwe specimen (as well as discussing the Krause case and the views on the human allantois of His and Kölliker).

102. See Franz von Preuschen, "Vorläufige Mittheilung über die Ergebnisse der anatomischen Untersuchung eines frischen menschlichen Embryo mit freier blasenförmiger Allantois (3,7 mm Länge)," *Mittheilungen aus dem naturwissenschaftlichen Vereine von Neu-Vorpommern und Rügen,* 1884, *12:* 25–37; idem, *Die Allantois des Menschen: Eine entwickelungsgeschichtliche Studie auf Grund eigener Beobachtung* (Wiesbaden: Bergmann, 1887); and, actually intervening to moderate anatomical objections to von Preuschen's work, "Ein Brief von Professor W. His, betreffend Professor von Preuschen's 'blasenförmige Allantois' beim Menschen. Mitgeteilt von Karl Bardeleben," *AA,* 1889, *4:* 17–21.

103. Carl Heinrich Stratz, *Die Entwicklung der menschlichen Keimblase* (Stuttgart: Ferdinand Enke, 1904), p. 2.

embryonic anatomy as a new area of specialization away from the diminishing returns of adult bodies; supply lines of material, as well as his own collection of sectioned embryos from which there remained much information to be reconstructed; his book as a starting point and model for microtomal analysis; and the *Normentafel* as a framework for arranging new embryos and giving broader significance to descriptions of single specimens. The biggest problem might have been that the methods of serial sectioning and reconstruction were, in the forms in which he pioneered them, unlikely to become widely distributed skills—but scientists at the Naples Zoological Station perfected the modern method of paraffin sectioning in the early 1880s, and Breslau anatomist Gustav Born developed a wax-plate technique to replace the very difficult freehand modeling.[104]

Though His established no school, he taught two anatomists who carried the new human embryology into the twentieth century: Keibel, and Franklin Paine Mall of Johns Hopkins. Mall owed his own training in embryology to His, with whom he worked in Leipzig in the mid-1880s, and he went on to become an exceptionally important teacher of American anatomists. He also followed His's lead in collecting human embryos, and founded the Carnegie Institution's Department of Embryology; under his successor, George L. Streeter, who also studied with His, this became the most important such collection in the world.[105] Keibel, in spite of his painfully slow progress through the German academic hierarchy, came to enjoy an international reputation as "praeceptor embryologiae."[106] In an early paper he described a new embryo, evalu-

104. Hopwood, "'Giving Body'" (n. 20).

105. On the history of the Carnegie department, see especially Florence Rena Sabin, *Franklin Paine Mall: The Story of a Mind* (Baltimore: Johns Hopkins Press, 1934); George W. Corner, *The Seven Ages of a Medical Scientist: An Autobiography* (Philadelphia: University of Pennsylvania Press, 1981), chap. 13; Loretta McLaughlin, *The Pill, John Rock, and the Church: The Biography of a Revolution* (Boston: Little, Brown, 1982), pp. 58–71; Donald D. Brown, "The Department of Embryology of the Carnegie Institution of Washington," *BioEssays,* 1987, *6:* 92–96; Clarke, "Research Materials" (n. 17); O'Rahilly, "One Hundred Years" (n. 10); and Lynn M. Morgan, "Materializing the Fetal Body, Or, What Are Those Corpses Doing in Biology's Basement?" in Morgan and Michaels, *Fetal Subjects, Feminist Positions* (n. 6), pp. 43–60. The Carnegie department was the dominant institution, but anatomist Erich Blechschmidt at Göttingen also built up a major collection; see his *Vom Ei zum Embryo: Die Gestaltungskraft des menschlichen Keims* (Stuttgart: Deutsche Verlags-Anstalt, 1968); and Klaus V. Hinrichsen, "In memoriam des Anatomen und Embryologen Erich Blechschmidt (1904–1992)," *Ann. Anat.,* 1992, *174:* 479–84.

106. Karl Peter, "Franz Keibel: Ein Nachruf," *AA,* 1929–30, *68:* 201–20, on p. 215. See also Rudolf Fick, "Gedächtnisrede auf Franz Keibel," *Sitzungsberichte der Preussischen Akademie der Wissenschaften. Physikalisch-Mathematische Klasse,* 1929, pp. cvii–cxxii; and Ernst Theodor

ated it according to His's criteria, arranged it in the series, and supported the master's view of the development of the allantois.[107] In a definitive study of the urogenital apparatus, he not only used the His *Normentafel* to stage new embryos by indicating which of the images they resembled most closely, he also reanalyzed series of sections that His let him take to Freiburg.[108] Yet while the *Normentafel* could act as a set of authoritative standards, anatomists describing new specimens could also treat it as provisional. In principle, they could remain true to the spirit of His's reforms while replacing every single embryo; but in practice, his norms proved rather robust.

Detailed analyses of individual human embryos accumulated until, in the first decade of the twentieth century, embryologists took stock. Keibel and Mall led a drive to consolidate the His-style human embryology in international handbooks and atlases.[109] Indeed, one of the most important uses of His's *Normentafel* was as a model for a set of sixteen *Normentafeln* of various vertebrates that were produced under Keibel's editorship between 1897 and 1938. In 1908 he and his student Curt Elze dedicated a new *Normentafel* of human development to the memory of the recently deceased His.[110] The authors' professions of continuity did not mask significant changes, however. Keibel and Elze could draw on many more, and also qualitatively different, embryos: several were younger than any His had collected, and more and more were obtained by hysterectomy or laparotomy. And the changes went deeper: a rising tide of scientific alarm about the dangers of subjectivity made scientists increasingly reluctant to grasp the nettle of selection. Texts shrank and atlases swelled with greater and greater numbers of less and less openly interpreted pictures.[111] Keibel and Elze still presented supposedly representative individuals, but it had become much harder to select them. In addition to a normal plate, and text descriptions of the embryos that it showed, they

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Nauck, *Franz Keibel: Zugleich eine Untersuchung über das Problem des wissenschaftlichen Nachwuchses* (Jena: Gustav Fischer, 1937).

107. Franz Keibel, "Ein sehr junges menschliches Ei," *AAP,* 1890, pp. 250–67. See also idem, "Ein menschlicher Embryo mit scheinbar bläschenförmiger Allantois," *AAP,* 1891, pp. 352–55.

108. Franz Keibel, "Zur Entwickelungsgeschichte des menschlichen Urogenitalapparates," *AAP,* 1896, pp. 55–156.

109. See esp. Keibel and Mall, *Manual* (n. 9); and also Julius Kollmann, *Handatlas der Entwicklungsgeschichte des Menschen,* 2 vols. (Jena: Gustav Fischer, 1907).

110. Keibel and Elze, *Normentafel* (n. 56). On Elze, see Walter Schmidt, "Curt Elze†," *AA,* 1976, *140:* 1–8. On the evolutionary significance of Keibel's *Normentafel* project, see Gould, *Ontogeny* (n. 63), pp. 174–75.

111. Daston and Galison, "Image" (n. 13).

drew on the work of anatomist Albert Oppel to introduce tables giving the degree of development of the organs of every embryo they depicted, and many others besides. Keibel and Elze showed great interest in the *normal* degree of variation among embryos, and offered the tabulated variations as data for later work on this topic. Including a large number of embryos in the tables would also, they said, reduce errors of selection.[112] In fact, no longer confident to make a representative series, they aimed—impossibly—for completeness. The text consisted of a short introduction and terse descriptions of each embryo, all of which put together were shorter than the massive 150-page bibliography, which again did not synthesize but brought together all available information and left it to users to make of it what they would.

The new *Normentafel* itself sent a new message. We saw how His conveyed an unambiguous sense of development by arranging the embryos in rows in sequence on a single plate, nearly all in the same view and all at the same magnification. Keibel and Elze's *Normentafel* distributed human development over six plates; the embryos were only approximately in developmental order, and were shown in various views at different magnifications. Surely their specialist audience needed little help from the layout. But the result, equally surely, and in spite of Keibel's expression of satisfaction with the huge progress of human embryology since the Krause affair, was to highlight the provisional state of scientific knowledge in the face of the complexity of the process and the difficulty of analysis.[113]

So that readers could quickly orient themselves with respect to His's long-standard embryos, Keibel and Elze incorporated a reduced copy of his *Normentafel* into their introduction (Fig. 8). A column in the tables defined embryos as "very similar to Fig. 14 of His's *Normentafel,*"[114] or "between Figs. 17 and 18 of His's *Normentafel.*"[115] Following His, the new *Normentafel* did not include other previously analyzed series, but in an article for the *Handbook of Human Embryology* that he edited with Mall a couple of years later Keibel did define a single best series of human embryos. Remarkably, he included most of His's norms (1, 2, 5, 7, 9–13, and 21–25), but judged the second, third, fourth, and sixth to be pathological because they showed the dorsal flexure that he reckoned a deformation due to postmortem swelling. The tenth he considered large for

112. On the design of the Keibel *Normentafeln,* see Franz Keibel, "Normentafeln zur Entwickelungsgeschichte der Wirbeltiere," *AA,* 1895, *11:* 225–34.

113. Keibel and Elze, *Normentafel* (n. 56), p. 89.

114. Ibid., p. 120.

115. Ibid., p. 128.

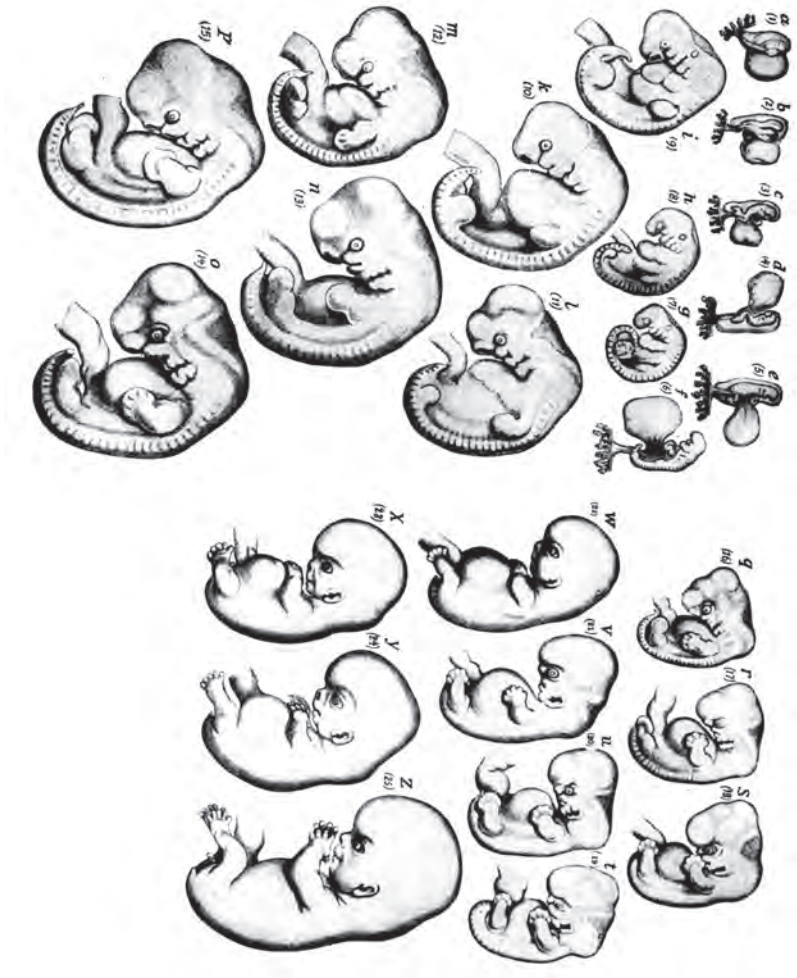

Fig. 8. Reproduction of the His *Normentafel* in the *Normentafel* of Keibel and Elze. (Franz Keibel and Curt Elze, with contributions from Ivar Broman, I. August Hammar, and Julius Tandler, *Normentafel zur Entwicklungsgeschichte des Menschen* [(Keibel, ed., *Normentafeln zur Entwicklungsgeschichte der Wirbeltiere,* vol. 8] [Jena: Gustav Fischer, 1908], Fig. 1; courtesy of the Wellcome Institute Library, London.) Elsewhere Keibel reproduced the figure upright.

its degree of development (as had His), and the twelfth to show some abnormality. Significantly, His's plate was actually reproduced, here as in the Keibel and Elze *Normentafel,* in a distorted form.[116] Keibel divided the embryos into two groups at different magnifications, so that some more-advanced embryos were smaller than some that had developed less far, probably partly because it was more convenient to enlarge the drawings of the younger embryos. Instead of neatly distinct rows, some of the embryos from one row were wedged into the next. Instead of a series of rows from left to right, the series snaked around—again, possibly more convenient, but also less clearly developmental. He put the numbers in parentheses, and complicated matters by also giving each embryo a letter. And finally, instead of printing the figure upright, he made readers of the *Normentafel* turn this page on its side. The completed appearance of His's series had been visually converted back into a collection of embryos from which the least abnormal would be selected as long as nothing better could be found, and of which the range of normal variation would also have to be defined.

Keibel and Elze, unable either fully to accept His's plate or decisively to move beyond it, show the limits of the *Normentafel* design. No longer confidently characteristic of developmental stages, individual embryos had become able to represent little more than themselves. As collections expanded, it became clear that an embryo might be more advanced in one respect but less so in another; hence the major practical problem that no unique series of human embryos could be defined, and a new embryo might simply not fit with the norms. Human embryologists at the Carnegie department would show a way out of the impasse: Streeter and his successors abandoned seriations for a more flexible system of stages based on several morphological criteria.[117]

Producing Development

Development has traditionally been taken for granted as what embryologists study, but it can be investigated as their achievement. I have shown for one series of developing embryos, the *Normentafel* in the *Anatomie menschlicher Embryonen*, how Wilhelm His can be said to have "produced" development. My analysis highlighted the practical problems of making

116. Franz Keibel, "Summary of the Development of the Human Embryo and the Differentiation of Its External Form," in Keibel and Mall, *Manual* (n. 9), pp. 59–90.

117. O'Rahilly, "One Hundred Years" (n. 10).

an ordered series of images of normally developing human embryos through the first two months of pregnancy: collecting what for anatomists were exceptionally rare objects, and framing them as embryos; rendering them into pictures that could be compared; arranging these in developmental sequence; selecting those most likely to represent normal development while excluding the pathological and the nonhuman; persuading other anatomists to take up the new standards of practice that sustained the norms; and, once established, revising them. In the process, I have shown how, and suggested why, His created a new human embryology that continued to set standards of embryogenesis through the twentieth century; enriched our picture of the transformation of the life and medical sciences around 1900 by highlighting a major but previously obscured innovation in turn-of-the-century embryology; and in a detailed study of atlas making, explored means of solving the problems of sequence and selection. I would like to close by outlining a few directions in which the approach recommended here might be extended.

Embryological standards include not just norms of human development over the *longue durée* from Soemmerring to His and from His to O'Rahilly and Müller (1987),[118] but also what are variously called "normal plates," "normal stages," or "normal tables" for other animals. The His and Keibel *Normentafeln* are a prime example of a line of "analytic" and "comparative" work that has been all but obliterated by the experimentalist ideology articulated in embryology around the same time and since dominant.[119] But experimental embryologists have often made normal plates for laboratory animals so that they could know as accurately as possible at what stage of development they were intervening, and could compare the results of that intervention to what they came to call "normal development." Producing normal stages has been part of domesticating these organisms for the embryological laboratory. Today, developmental biologists consult the atlases that describe standard stages for commonly used organisms almost as frequently as manuals of molecular cloning techniques.[120]

118. Ronan O'Rahilly and Fabiola Müller, *Developmental Stages in Human Embryos, Including a Revision of Streeter's "Horizons" and a Survey of the Carnegie Collection* (Washington, D.C.: Carnegie Institution of Washington, 1987).

119. See Pickstone, "Museological Science?" (n. 3).

120. For examples of normal stages or normal tables by famous experimentalists, see Viktor Hamburger and Howard L. Hamilton, "A Series of Normal Stages in the Development of the Chick Embryo," *J. Morphol.,* 1951, *88:* 49–92; Pieter D. Nieuwkoop and Job

Development is "produced" not only in those relatively rare cases when embryologists formally define norms, but in most passages of embryological work. Embryological activity not only presupposes development—and often a normal table or other atlas setting out what to expect of the embryos under study—among its most important products it also generates new developmental series. From laying out a museum gallery, to making a set of autoradiographs showing changing patterns of gene expression through fruit-fly development, to generating successive ultrasound images of a human pregnancy, the practices whereby developmental series are produced and reproduced, used and modified, displayed and negotiated, offer historians and sociologists of science and medicine a rich field of investigation. But we might paint the history of seriality in the life sciences on a very much broader canvas, and investigate series of developing embryos, as they have so often been displayed, alongside series, especially, of adult animals and fossils.

Returning to embryology but looking more widely, we can ask how embryological visions fared beyond the anatomical institutes. Long before such American popularizations of the new human embryology as Margaret Shea Gilbert's *Biography of the Unborn* (1938), let alone photographer Lennart Nilsson's *Time* magazine spread of 1965,[121] series of human embryos were already on display to wide audiences. But that does not mean they were uncontroversial: Keibel finished his *Normentafel* only to be involved in a second phase of the row over Haeckel's pictures.[122] His's *Anatomie* was itself relatively inaccessible, but versions of his developmental series soon joined a wide variety of embryos in public arenas, from the figures in Haeckel's books to the aborted fetuses shown at hygiene exhibitions. In the Weimar Republic, for example, socialist physician and best-selling author Max Hodann reproduced some of His's drawings in a widely read sex-education pamphlet for children called

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Faber, eds., *Normal Table of* Xenopus laevis *(Daudin): A Systematical and Chronological Survey of the Development from the Fertilized Egg till the End of Metamorphosis* (Amsterdam: North-Holland Publishing, 1956, and later eds.). Others are cited by contributors to Jonathan B. L. Bard, ed., *Embryos: Color Atlas of Development* (London: Wolfe, 1994). On the history of the genre, see Nick Hopwood, "Standards of Development: A History of the Normal Table," paper presented at the ISHPSSB meeting in Oaxaco, Mexico, 10 July 1999.

121. Margaret Shea Gilbert, *Biography of the Unborn* (London: John Murray, 1939 [1938]). See also George W. Corner, *Ourselves Unborn: An Embryologist's Essay on Man* (New Haven: Yale University Press, 1944); and on Nilsson's images see, e.g., Duden, *Disembodying Women* (n. 7), pp. 11–24; Franklin, "Fetal Fascinations" (n. 6). On communicating human embryology in the United States in the 1930s and 1940s, see Catherine Cole, "Sex and Death on Display: Women, Reproduction, and Fetuses at Chicago's Museum of Science and Industry," *Drama Rev.,* 1993, *37* (1): 43–60; and Morgan, "Materializing the Fetal Body" (n. 105).

122. On which, see Gursch, *Illustrationen* (n. 63), pp. 84–136.

"Does the Stork Really Bring Us?"[123] More vivid than drawings were the wax models, which His said would "give body" to human development. As part of a drive to warn women insured with the sickness funds of the dangers of abortion, "social gynecologist" Wilhelm Liepmann showed the His-Ziegler models in his Berlin Museum for the Study of Women.[124] What differences did these embryological images make? How were pictures and models of embryos used by anatomists, science popularizers, health educators, sex reformers, general practitioners, midwives, and (not least) pregnant women? How did these representations challenge or become assimilated to other images of pregnancy? How have anatomical atlases of embryonic and fetal development been used in the clinical monitoring of pregnancy by X rays, and later ultrasound?

To show development being produced we have had to enter into the nitty-gritty of embryological work. Yet telling the story of Krause's embryo allowed me to indicate one way in which the normalizing practices I have focused on in this paper were deployed in the service of the more traditional concerns of historians of late-nineteenth-century German life and medical sciences. How a specific embryo should be documented, drawn, and dissected was at issue in disciplinary and wider political struggles that have previously been analyzed in terms of clashes of theories and programs. Provided we understand embryologists as working at nodes in circuits of production and communication, and hence as interacting with a host of other actors, taking routine embryological practices seriously need not narrow our view but should actually open new connections to social and cultural history and the politics of the body.

123. Max Hodann, *Bringt uns wirklich der Klapperstorch? Ein Lehrbuch für Kinder lesbar,* 2d ed. (Rudolstadt: Greifenverlag, 1928), p. 13. On Hodann, see Wilfried Wolff, *Max Hodann (1894–1946): Sozialist und Sexualreformer* (Hamburg: von Bockel, 1993); and on the sex-reform movement in which he was active, Cornelie Usborne, *The Politics of the Body in Weimar Germany: Women's Reproductive Rights and Duties* (Basingstoke, U.K.: Macmillan, 1992); and Atina Grossmann, *Reforming Sex: The German Movement for Birth Control and Abortion Reform, 1920–1950* (New York: Oxford University Press, 1995).

124. On modeling embryos, see Hopwood, "'Giving Body'" (n. 20). For Liepmann's use of His's models, see *Das Volksmuseum für Frauenkunde Berlin* (Berlin: Deutsches Institut für Frauenkunde, [1929]), p. 33; Peter Schneck, "Zur Geschichte der sozialgynäkologischen Ideen, Projekte und Institutionen in Deutschland während des ersten Drittels des 20. Jahrhunderts" (Dr. sc. med. diss., Humboldt University Berlin, 1983), pp. 120–23; Monika von Oertzen, "Das Volksmuseum für Frauenkunde (1929–1933) in Berlin: Eine Position zur Abtreibungsfrage in der Weimarer Republik," in Staupe and Vieth, *Unter anderen Umständen* (n. 7), pp. 51–57; and idem, "'Gesunde Mütter, gesundes Volk!': Das Volksmuseum für Frauenkunde—eine sozialgynäkologische Einrichtung der Weimarer Zeit," *Mitteilungen der Magnus-Hirschfeld-Gesellschaft,* June 1993, *18:* 41–52.