A Contemporary Aristotelian Embryology

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IN NICANOR PIER GIORGIO AUSTRIACO fine book *Biomedicine and Beatitude: An Introduction to Catholic Bioethics,* he addresses a topic that the two authors of the present article have discussed with him several times, especially at meetings organized by the Westchester Institute under the leadership of Fr. Thomas Berg. That topic is the beginnings of life—or embryology—as understood by contemporary scientists and by the Catholic tradition.

With good reason, Fr. Austriaco criticizes authors such as Joseph Donceel for arguing in favor of the Aristotelian-Thomistic conception of delayed hominization and, therefore, at least in Donceel's case, for the morality of early induced abortions. As Fr. Austriaco explains:

> According to the theory of delayed hominization, the embryo passes through stages of vegetative and animal ensoulment before arriving at a human stage when the body is sufficiently organized and developed for the infusion of the rational soul by

the immediate action of the Creator.[1]

He goes on then to argue that this approach to embryology is no longer sustainable because Aristotle, followed by Thomas, thought that "hominization could be completed only after a period of time after fertilization, when the human organism came into being from the gradual action of the father's semen on the mother's menstrual blood." This gradual action produces (at least according to some interpretations of Aristotle) first a vegetative soul, then a sensitive soul, and finally a rational (or human) soul. We now know, says Fr. Austriaco, "that the human organism is present once fertilization begins when the sperm and the egg physically interact."[2]

The present authors agree with this, that is, that the rational soul is present from the moment of fertilization.[3] And yet we also maintain that, having once rejected Aristotelian biology strictly speaking, based as it is upon what Aristotle was able to see with his naked eye, the contemporary biologist and/or ethicist can remain philosophically Aristotelian. He or she can maintain that hominization occurs at the moment of fertilization in a manner consistent with Aristotle's metaphysics (broadly construed), especially his understanding of the relationship between form and matter and his understanding of the rational soul. Showing that this is a tenable position is no mere game: an exercise in which we try, with no further purpose, to match up ancient and contemporary ideas. We hope to show that Aristotle's view of the soul and of human

[1] Nicanor Pier Giorgio Austriaco, O.P., *Biomedicine and Beatitude: An Introduction to Catholic Bioethics* (Washington, DC: The Catholic University of America Press, 2011), 59. The Donceel article Fr. Austriaco cites is Joseph F. Donceel, "Immediate Animation and Delayed Hominization," *Theological Studies* 31 (1970): 76–105. On Aristotle's embryology, see Kevin L. Flannery, "Applying Aristotle in Contemporary Embryology," *The Thomist* 67 (2003): 249–78.

[2] Austriaco, *Biomedicine and Beatitude*, 60. At this point, he cites a reprint of Maureen L. Condic, "When Does Life Begin? A Scientific Perspective," *Westchester Institute White Paper Series* 1 (2008): 1–18. The reprint appears at *National Catholic Bioethics Quarterly* 9 (2009): 129–49.

[3] One problem in saying that the rational soul is present from the moment of fertilization has to do with the phenomenon of monozygotic twinning. We do not address this problem in the present essay; it is addressed, however, in Flannery, "Applying Aristotle in Contemporary Embryology," especially pp. 270–75.

nature (and therefore a large portion of the corpus of his thinking) is consistent with modern science.

"No Walking without Feet"

Aristotle's definition of the soul is as follows: "the first actuality of a natural body having life potentially"; he goes on then immediately to say that "such a body is a body that is organic" [*De anima* ii,1, 412a27-8]—that is, possessing organs potentially alive with a particular type of soul.[4] As we shall explain more fully below, this definition is packed with implicit metaphysical content, but we would make only the following point here at the beginning. An approach based on such a definition is one of the few ways of avoiding unacceptable varieties of dualism. It allows, as we shall see, for the separability and immortality of the rational soul, even while it ensures that the human soul cannot be found in another body or a body of another type: in a dove's body, for instance, or even in a basketball.[5]

The reason why Aristotle held that there is gap between conception and the moment at which the rational (human) soul enters into the material contributed by the menses of the embryo's mother is that he held, as we have seen, that for a soul to be present the corresponding organic structure has to be present. In the third chapter of the second book of his *Generatione animalium* [*GA* ii,3], Aristotle expresses this principle in a usefully epigrammatic manner. He is considering the possibility that the vegetative, sensitive, and rational souls preexist in the embryo, as distinct from the possibility that they are introduced from outside.[6] His position is as follows:

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[4] The word "actuality" translates the Greek ἐντελέχεια, which refers to the existence of something as a substance of a particular type. A "first actuality" is (obviously) the first state of such a substance. In what follows, Aristotle's *De anima* is abbreviated *De an.*; other abbreviations include *GA* for *De generatione animalium*; *HA* for *Historia animalium*; *PA* for *De partibus animalium*.

[5] On the immortality of the rational soul, see also, for instance, Martha C. Nussbaum and Hilary Putnam, "Changing Aristotle's Mind," in *Essays on Aristotle's* De Anima, ed. Martha C. Nussbaum and Amelie Oksenberg Rorty (Oxford: Clarendon Press, 1992), 27–56.

[6] By "preexisting" Aristotle means already existing either in the semen or in the embryo. In this article we make use of the Revised Oxford Translation (Jonathan Barnes, ed., *The Complete Works of Aristotle: The Revised Oxford Translation* [Princeton:

> Now, that it is impossible for them all to preexist is clear from this consideration. Plainly those principles whose activity is bodily cannot exist without a body, e.g. walking cannot exist without feet. For the same reason also they cannot enter from outside.[7]

It appeared to Aristotle that, at the beginning of its existence, the embryo has no organic structure—in *Historia animalium*, he says that early on the embryo "consisted of a fleshlike substance without distinction of parts" [ἄναρθρον συνέστηκε κρεῶδες—*HA* vii,3, 583b9–11]—and so there is nothing to which a preexisting soul could attach itself. Nor could such a soul be introduced from without, since it would have to have in its exterior state a supporting structure; but the sperm, like the embryo itself, is (according to Aristotle) without any such structure. He goes on immediately to add that, since reason's activity is not bodily—indeed, as he puts it, "no bodily activity has a part in the activity of reason" [*GA* ii,3, 736b28-29]—it alone enters from outside and so is divine.[8] But, even still, it cannot enter in right at the beginning, since it *depends* upon the presence of a sensitive soul (or faculty) whose activity is bodily and the sensitive faculty itself cannot exist at the beginning, since no appropriate organ is present then. Just as a sensitive soul cannot exist in a basketball, human reason—which is different from the reason present in non-material substances—cannot exist anywhere except in an animal that has a sensitive faculty.

When Aristotle says that the vegetative, sensitive, and rational souls cannot be present in the embryo until a supporting organ is present, he does not mean that the full organ must be there, "up and running"; he means only that there must be something there—something with organic structure—that will become such an organ and that is moving on its own in that direction. This becomes apparent in a number of passages. In *GA* ii,6, for instance, he says that the embryo must have a "principle of movement and of generation," along with the end toward which it is directed, plus that which it uses in going there [742a27–32]. He eventu-

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Princeton University Press, 1984]), occasionally slightly revised.

[7] *GA* ii,3, 736b22–25.

[8] In *De an.* iii,5, Aristotle will argue that (at least) part of the intellect is immortal; once it is separated from the body and therefore from the sensitive faculty, it cannot do any *thinking*, but it does exist. See especially *De an.* ii,5, 430a22–25.

ally identifies the organ that contains the principle of movement in animals as the heart [742b36]—which is (as we might put it) the "organ of origin" for both the vegetative and sensitive souls.[9] This organ must exist from the beginning, for it is that from which grow all the other organs:

> Therefore, all the organic parts whose nature is to bring others into being must always themselves exist before them, for they are for the sake of something else, as is a principle; all those parts which are for the sake of something else but are not of the nature of beginnings must come into being later [*GA* ii,6, 742b3–6].[10]

Since this organ is so bound up with movement—it and the principle of movement are dependent on each other for their very existence—the moment that there is independent movement in the embryo, necessarily, as much development of the organ as is needed for the presence of the principle is present. The movement is the key: once that is present in even a very small, relatively unarticulated part, there is no reason to deny that the corresponding soul is present. Someone positing its later arrival would be hard pressed to explain the independent movement toward that stage at which he maintains the soul arrives.[11]

Scientific Evidence of Independent Movement from Conception

It is scientifically certain that such a primordium, or principle of movement toward development of the nervous system, exists in the embryo from the moment of conception. In the instant of sperm-egg fusion,

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[9] See *PA* iii,4, 666a11–13, where Aristotle says: "the motions of pain and pleasure, and generally of all sensation, plainly have their source in the heart, and find in it their ultimate termination"; see also *GA* ii,6, 742a32–33, regarding locomotion. See also *GA* ii,6, 742b1, where Aristotle says that the heart is in animals the "principle and end of all their nature."

[10] See also *GA* ii,4,740a17–21: "Therefore it is that the heart appears first distinctly marked off in all the sanguinea, for this is the first principle of both homogeneous and heterogeneous parts, since from the moment that the animal or organism needs nourishment, from that moment does this deserve to be called its principle, for that which exists grows."

[11] We have been helped in the formulation of this point by Fr. Stephen L. Brock of the Pontifical University of the Holy Cross, Rome.

a new cell, the zygote, comes into existence, a cell that is clearly distinct from either of the gametes. This new cell contains all the molecular components of both sperm and egg, and therefore has a unique material composition. Moreover, it immediately enters into a pattern of behavior that is characteristic of an embryo, and quite distinct from the behavior of gametes. Sperm and egg are specialized cells that are uniquely organized to accomplish fertilization. Once they are fully mature, if fertilization is not accomplished, they persist for approximately 24 hours before naturally degenerating. In contrast, the newly formed zygote enters into a sequence of events directed toward the ongoing development and health of the embryo as a whole, building structures and relationships that will persist for decades until the death of the individual. Clearly, an independent movement toward maturation (rather than merely toward fertilization) has been initiated in the zygote.[12]

Yet what are the organic parts that constitute the primordia of the nervous system? And is this organic material present from the very beginning? The zygote exists in a very specific state that is uniquely capable of development. There are three basic components of the "program" for development.[13] First, the zygote has specific molecules (transcription factors, enzymes, DNA binding proteins, etc.) that are unique to the embryo and required for a normal pattern of development. Second, the zygote has uniquely modified DNA and associated proteins (i.e., a specific epigenetic state) that is not found in other cell types. Finally, the DNA derived from sperm and egg each carries a particular pattern of maternal and paternal "imprinting" (i.e., chemical alterations to the DNA that regulate how it is used). These three components work together in complex ways to generate all of the cells, tissues, structures, and organs required for life, including the nervous system.

Importantly, this developmental program does not come into existence gradually, but rather all three necessary components are present from the instant of sperm-egg fusion. Further, this program is specifically *human* (human embryos do not develop into monkeys or oak trees), and uniquely *individual* (even identical twins do not have iden-

[12] See Condic, "When Does Life Begin? A Scientific Perspective."

[13] For a more detailed discussion, see Maureen L. Condic, "A Biological Definition of the Human Embryo," in *Persons, Moral Worth, and Embryos: A Critical Analysis of Pro-Choice Arguments,* ed. Stephen Napier (New York: Springer, 2011), 211–37.

tical developmental programs).[14] Thus that which is physically required for movement toward the maturation of a particular human body (the primordia of an individual's mature state) exists from the moment of sperm-egg fusion onward. This program, inherently bound to the very structures of the embryo itself, is the "organ" that contains the principle of movement for the zygote's subsequent maturation.

The execution of this developmental program (or the movement of the primordia toward a mature state) can be seen from the very beginning of life. Within a minute of sperm-egg fusion, the zygote initiates a sequence of chemical changes (i.e., the cortical reaction) that will rapidly block any additional sperm from binding to the cell surface. This is clearly different from the function of an egg cell (the primary purpose of which is to bind to sperm). Moreover, the cortical reaction is initiated by molecules contributed by the sperm, showing that molecular elements of the zygote derived from both parents interact in a coordinated manner to produce the steps required for normal development.[15] Importantly, this initial act of the zygote to prevent fusion with more than one sperm is not merely directed toward growth (i.e., a vegetative function); oocytes that are abnormally fertilized by more than one sperm produce tumors that are perfectly capable of cell division or growth, but they do not undergo development and are not embryos. Rather, the cortical reaction is directed toward preserving the normal (diploid) genetic state that is required for development of the embryo as a whole. Thus, the cortical reaction anticipates the future requirements of the embryo, and can only be understood as the first step in a

[14] G. Manchin, "Non-identical monozygotic twins, intermediate twin types, zygosity testing, and the non-random nature of monozygotic twinning: a review," *American Journal of Medical Genetics. Part C, Seminars in Medical Genetics* 151C (2) (2009): 110–27; W. Czyz et al., "Genetic, environmental and stochastic factors in monozygotic twin discordance with a focus on epigenetic differences," *BioMed Central Medicine* 10 (2012): 93–104.

[15] S. Y. Yoon et al., "Recombinant human phospholipase C zeta 1 induces intracellular calcium oscillations and oocyte activation in mouse and human oocytes," *Human Reproduction* 27 (2012): 1768–80; M. Nomikos, K. Swann and F. A. Lai, "Starting a new life: sperm PLC-zeta mobilizes the Ca2+ signal that induces egg activation and embryo development: an essential phospholipase C with implications for male infertility," *Bioessays* 34 (2012): 126–34.

sequence of events that is uniquely ordered toward the production of the mature organs of the body.

An Objection

So, it is apparent that, contrary to what Aristotle says (since he speaks of what he was able to see with the naked eye), there is organic structure in the embryo right from the beginning. But at this point an objection can be voiced.[16] It might be expressed in the following way: "You have, indeed, shown that right from the beginning there is organic material in the embryo that will become (if not impeded) the body of a mature human being. You have also shown that Aristotle does not require that there be present the fully developed organ that allows for the presence of the rational soul: what is necessary is organic material that will, if not impeded, move toward the body of the mature human being. But is the necessary condition that you have identified (organic material that will "move toward") enough to satisfy Aristotle's insistence that there can be no soul present unless the corresponding organic structure is present ('no walking without feet')? Aristotle requires the presence of a *particular* organic structure to which a soul might be attached; but, as you know, at the very earliest stages of embryo development, the various cells that will go on to develop into the body of the mature human being have not yet been assigned to a particular part of the developed body."

This objection is supported by ample scientific evidence that indicates there is no "particular" cell or group of cells that is exclusively responsible for the formation of the nervous system. Whereas in some animals, molecular factors that specify a particular pattern of development are differentially inherited by early cells of the embryo, in humans and other mammals, cell-cell communication plays a large role in determining precisely what path a specific cell will follow (i.e., mammalian development is largely "regulative" rather than "determined"). Consequently, in many cases, the cells of the early embryo randomly contribute "descendants" or progeny to multiple mature tissues as de-

[16] The following objection is similar to one posed to the present authors by Ryan Madison, Associate Director of the Notre Dame Center for Ethics and Culture, University of Notre Dame. We are grateful to him for the insight.

velopment proceeds.[17] Even after the earliest primordium of the nervous system (i.e., the neural plate) has formed, cells that are initially part of this primitive structure will ultimately leave the developing brain and migrate throughout the body to contribute to tissues as diverse as the skull, the skin, and the heart.[18] It is only relatively late in embryonic development (during the fifth week) that cells within the forming nervous system become restricted to producing only nervous tissue.

In addition to the fact that early cells of the embryo are not restricted to an exclusively neural fate, generation of the mature nervous system requires input from multiple tissues that do not themselves make cellular contributions to the brain. For example, formation of the head, including the portions of the brain most directly related to rational thought, requires molecular signals from a primitive gut-derived tissue known as the prechordal plate.[19] Conversely, molecular signals from the developing eye[20] and forebrain[21] are critical for the correct formation of the bones and muscles of the face, despite the fact that these neural tissues do not contribute cells to developing facial structures. These observations indicate that even relatively late in embryonic development (eye formation begins approximately halfway through embryonic life, in the fourth week), there are no "specialized" tissues that are exclusively responsible for the generation of either the brain or the face. In the vast majority of cases, multiple tissues interact repeatedly during embryonic

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[17] The regulative nature of early mammalian development is discussed in detail in: "The first cell-fate decisions in the mouse embryo: destiny is a matter of both chance and choice," M. Zernicka-Goetz, *Current Opinions in Genetics and Development* 14 (2006): 406–12.

[18] M. S. Prasad, T. Sauka-Spengler, and C. LaBonne, "Induction of the neural crest state: control of stem cell attributes by gene regulatory, post-transcriptional and epigenetic interactions," *Developmental Biology* 366 (2012): 10–21.

[19] S. Piccolo et al., "The head inducer Cerberus is a multifunctional antagonist of Nodal, BMP and Wnt signals," *Nature* 397 (1999): 707–10; C. Niehrs et al., "Dickkopf1 and the Spemann-Mangold head organizer," *International Journal of Developmental Biology* 45 (2001): 237–40; F. Müller and R. O'Rahilly, "The prechordal plate, the rostral end of the notochord and nearby median features in staged human embryos," *Cells Tissues Organs* 173 (2003): 1–20.

[20] P. E. Kish et al., "The eye as an organizer of craniofacial development," *Genesis* 49 (2011): 222–30.

[21] D. Hu and R. S. Marcucio, "Unique organization of the frontonasal ectodermal zone in birds and mammals," *Developmental Biology* 325 (2009): 200–210.

development to coordinately produce all of the mature structures of the body, including the nervous system.

Finally, even on a molecular level there is no single (i.e., "particular") organic structure exclusively responsible for the formation of the brain. A curious aspect of embryonic development is that the same molecules are used repeatedly at different times to generate both different structures and different elements of the same structure. And quite often, specific molecules function in what appear to be contradictory ways as a tissue matures. For example, a family of signaling molecules known as Bone Morphogenetic Proteins (or BMPs) initially inhibits formation of the nervous system, but at later developmental stages, BMPs are required to maintain specialized populations of neural cells and to promote normal brain patterning.[22] In addition, BMPs play important roles in the formation of many structures outside of the nervous system, including limbs,[23] kidneys[24] and (of course) bones.[25] Thus, BMPs contribute to a wide range of developmental processes, and despite their critical role in brain development, these molecules cannot be seen as "a particular organic structure to which a soul might be attached." And so (the objection would go) the necessary condition epitomized in Aristotle's epigram "no walking without feet" has not been met.

The Artist and His Material

The answer to this objection, however, is implicit in what we have already said about the directed movement that occurs right from the beginning of the embryo's existence; but there is a passage in Aristotle in which the basis of the proper response is made more explicit. In it, he speaks about the first moment in which the embryo moves on its own. This occurs, he says, "when the active and the passive come in contact

[22] A. M. Bond, O. G. Bhalala, and J. A. Kessler, "The dynamic role of bone morphogenetic proteins in neural stem cell fate and maturation," *Developmental Neurobiology* 72 (2012): 1068–84.

[23] B. Robert, "Bone morphogenetic protein signaling in limb outgrowth and patterning," *Development, Growth and Differentiation* 49 (2007): 455–68.

[24] J. E. Cain et al., "Bone morphogenetic protein signaling in the developing kidney: present and future," *Differentiation* 76 (2008): 831–42.

[25] M. Wan and X. Cao, "BMP signaling in skeletal development," *Biochemical and Biophysical Research Communications* 328 (2005): 651–57.

with each other in that way in which the one is active and the other passive (I mean in the right manner, in the right place, and at the right time)" [*GA* ii,4, 740b21–24). He continues:

> The female, then, provides matter, the male the principle of movement. And as the products of art are made by means of the tools of the artist,[26] or to put it more truly by means of their movement, and this is the activity of the art, and the art is the form [μορφὴ] of what is made in something else, so is it with the power of the nutritive soul. [*GA* ii,4, 740b24-29]

Although Aristotle is speaking here about the very earliest independent existence of the embryo—at which stage he did not see sufficient structure to support a sensitive or a rational soul—what he says is applicable at later stages, for he goes on to make this application in the lines that immediately follow.

The principle of movement—which in the human embryo is the rational soul—is, therefore, like an artist who uses his tools upon appropriate material. In any such scenario, the artist is in charge. He can take up whatever material he chooses, provided it is appropriate material, and, when the moment is right, he can shape that material into any part of the art's product for which it is appropriate. In an embryo, "the artist," although in charge, is also directly dependent upon his material. For the principle of movement to *be* a principle of movement, there must be present the appropriate organic material; but, once the material is there, the principle of movement is also there. Movement requires both an active and a passive element.

So, the fact that the cells that are part of the early embryo (for instance) might end up in various sectors of the developed or developing embryo does not mean that the principle of movement "had no feet" at that early stage. Such would be impossible: for then the principle of movement would not be a principle of movement. At the earliest stage (the one-cell zygote), the principle of movement has feet (i.e., the appropriate organic material): the molecules subject to the develop-

[26] The word used in this sentence, τέχνη, might also be translated "craft," so the person practicing the τέχνη might also be called a craftsman.

mental "program" of the embryo, which are suitable for the movement effected at that stage. When the time for cell differentiation arrives, the feet required for that particular movement are also present. Indeed, in a sense, at that point the principle of movement has a "choice" of feet[27] (i.e., a group of cells, any one of which may be developmentally competent to advance in a particular direction). The embryo is programmed to assign to some organic material a particular role that other organic material might have filled just as well, just as the former material might have filled the latter's assigned role. What material goes where is in this sense "arbitrary," although it is not arbitrary that each role must be filled by distinct organic material. When the embryo moves into the cell differentiation phase, we know exactly what organic material is being—and shall be—used in the further development of the embryo, and in what manner.

Unity and "Random" Selection

The biological evidence also supports the conclusion that the organic material necessary for the presence of the human soul (i.e. the "developmental program") cannot come into existence as a consequence of embryonic development *itself*. From the fusion of sperm and egg onward, the human embryo is unambiguously a human organism—that is, an integrated whole being that immediately begins to function in a coordinated manner to generate the structures of the body in an orderly sequence. This orderly pattern of maturation is the defining characteristic of an organism at an immature stage of its life cycle that distinguishes an organism from a mere cell. Consequently, it is both illogical and inconsistent with the facts to assert that the human embryo somehow "develops" the characteristics of an organism over time. Embryos are organisms precisely by virtue of the fact that they undergo development in the first place.

In contrast to embryos, tumors will produce a range of different cell types, but they do not progress through an orderly sequence of stages that culminates in a single mature form. They do not "develop" and they are not organisms. Indeed, if a tumor were to spontaneously give rise to

[27] It would be a mistake, however, to speak of a choice such as a rational being might make.

a human baby, this would be an unprecedented and inexplicable biological event precisely because no movement toward maturation pre-existed in the tumor.

How then, do we view the regulative or random aspects of mammalian development? As noted above, the fact that cells may "arbitrarily" contribute to a particular structure (e.g. the nervous system) does not make the process of development *random*. Random cellular events result in the formation of *tumors*: collections of differentiated cells with no consistent relationship to each other or to the tumor as a whole. In contrast, embryos—even embryos with a largely "regulative" pattern of development—never exhibit the random behavior of a tumor. In embryos, specific cell types arise at predictable times, in specific places, and in appropriate numbers to result in a characteristic mature human body. The developmental mechanisms used to produce this orderly outcome may (at times) involve random selection of a particular cell from a larger group of cells that are all equally competent to take up the task.[28] Yet the outcome itself is entirely determined by the developmental program that specifies the orderly (i.e., non-random) progression of these events. And, as we have already noted, this program constitutes the "feet" that are required for the forward movement of development.

Most species use multiple developmental mechanisms to ensure that specific cells are produced in the right place, at the right time, and in the right numbers. There is strong evidence that in the majority of mammalian embryos, cell fates are determined (or at least "biased") by the time the four-cell stage is reached, because of differential inheritance of specific molecular factors from the one-cell embryo.[29] Yet in the minority of cases in which this differential inheritance does not occur, other mechanisms involving cell-cell communication ensure that the same outcome will be obtained. These overlapping, redundant mechanisms reflect the developmental program that came into existence in the

[28] In embryology, groups of cells with identical developmental competence are known as "equivalence groups." See G. S. Stent, "The role of cell lineage in development," *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 312 (1985): 3–19.

[29] M. Zernicka-Goetz, "Cleavage pattern and emerging asymmetry of the mouse embryo," *Nature Reviews. Molecular Cell Biology* 6 (2005): 919–28; M. Zernicka-Goetz, "Development: do mouse embryos play dice?" *Current Biology* 7 (2013): 15–7.

moment of sperm-egg fusion, and they produce a consistent movement toward a mature state

Conclusion

We conclude, therefore, that the (broadly construed) metaphysical principles implicit in Aristotle's treatment of the early stages of embryonic life are by no means incompatible with contemporary science, at least with regard to the issues discussed here. Indeed, they shed light upon what is now known to occur at those early stages. That is to say, they provide means of accounting for and describing the dynamic unity present in the embryo from the moment of conception. Obviously, many of the empirically based details of Aristotle's biology must be rejected; but we embrace readily the philosophical principle that there is "no walking without feet." N&V