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The Mathematics (and Metaphysics) of Identical Twins

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Abstract

The metaphysics of early embryos is a hotly debated topic in contemporary bioethics and metaphysics. Many contemporary Aristotelians believe that a human being is present from the moment of conception. At the same time, certain findings in modern embryology about the formation of identical twins challenge this belief. It becomes much harder when these theories are taken into account to understand the continued identity over time of the embryo(s) given the twinning process. In this paper I will consider the philosophical implications of two models of monozygotic (MZ) twinning within an Aristotelian metaphysical schema, one of which is the standard, or traditional, model, and the other of which is a new model recently put forward by Herranz (2013). For the sake of completeness, I will also consider the philosophical implications of chimeras for the Aristotelian position. I will explain how Aristotelians can understand the process of twinning whilst holding on to their belief that a human being is present from the moment of conception.

1) Twinning

In this paper I will consider the philosophical implications of two models of monozygotic (MZ) twinning, one of which is the standard, or traditional, model, and the other of which is a new model recently put forward by Gonzalo Herranz (2013). For the sake of completeness, I will also consider the philosophical implication of chimeras.

Before I begin it is worth clarifying some technical terms and giving a very approximate description of a regular ‘singleton’ pregnancy (i.e. one not involving twins). In a regular pregnancy, when a sperm fertilizes an ovum a single-celled zygote results. This zygote then moves down the Fallopian tube. As it does so it divides resulting in a blastocyst. When the blastocyst reaches the womb it implants itself, usually after nine or ten days. A placenta forms, followed by an outer chorionic membrane, followed by an inner amniotic membrane. When the amnion or amniotic sac is formed the blastocyst is considered an embryo. Eight weeks after fertilization the embryo is considered a fetus. Ten weeks after fertilization almost all of the organs are more or less formed, albeit very undeveloped. At 24

weeks the fetus stands a reasonable chance of surviving outside the womb (given current medical technology). Normally, however, the fetus continues to grow and approximately nine months after fertilization the fetus is born. Obviously, this is a very approximate description, and all of the terms used here are contentious to some extent (due to both scientific and ideological reasons). Hopefully, however, this description is accurate enough for the purposes of this paper and is phrased in an ideologically neutral manner.

Dizygotic (i.e. non-identical) twins result when two ova are released and are fertilized by two separate sperm. These twins then, usually, develop side by side, but separately (except for chimeras). For our purposes dizygotic twins do not raise any questions about personhood and identity not raised by singleton pregnancies. It is simply that there are two zygotes/embryos/fetuses present in the womb at the same time, rather than the usual single zygote/embryo/fetus. This is no more mysterious than there being two adults in the same room at the same time. Thus, with regard to the aims of this paper, dizygotic pregnancies are uninteresting. In this paper I will be interested in the identity of monozygotic twins (i.e. identical twins). It is to the development of monozygotic twins that I now turn.

Two basic premises are assumed in the traditional model of monozygotic (MZ) twinning. The first is that monozygotic twinning occurs after fertilization due to the splitting of an early embryo. The second is that the timing of the splitting determines chorionicity and amnionicity. If the splitting occurs one to three days after fertilization the fetuses will have separate chorionic (outer) membranes (and thus placentas) and separate amnions (inner membranes). This is called a dichorionic diamniotic (DC/DA) twin pregnancy. If the splitting occurs between five and eight days, the fetuses will share a single chorionic membrane with separate amnions. This is called a monochorionic diamniotic (MC/DA) twin pregnancy. If the splitting occurs between nine and thirteen days, fetuses will share a single chorionic membrane and a single amnion. This is called a monochorionic monoamniotic (MC/MA) twin pregnancy. If the splitting occurs at fourteen days or later (after the appearance of the primitive streak) conjoined twins will result. Put very simply and unscientifically, the earlier the twins split the more 'separate' they will be, the later they split the more 'together' they will be.

Herranz has recently proposed a new model for twinning (Herranz, 2013). The new model also rests on two premises, but these are different from the premises assumed by the traditional model. According to Herranz's model the two premises are:

“1. All MZ twinning is the result of the first zygotic division. In other words, in the case of MZ twinning, the first cleavage division of the fertilized egg, instead of giving origin to two blastomeres, generates twin zygotes.

2. The structure of the fetal membranes does not depend on the splitting of an embryo, but on different modes of fusion of the membranes of the twin embryos within the pellucida (or, in the case conjoined twins [sic], of the two embryonic bodies)” (Herranz, 2013, p. 33).

Put simply and unscientifically, the fertilized egg, rather than splitting into a two-celled blastocyst, splits into twin single-celled zygotes. As a result, the twins are separate from the earliest stages of the pregnancy and may then ‘merge’ back together to some extent, either sharing only a chorionic membrane, a chorionic membrane and an amnion, or bodily fusing together to form conjoined twins.

It is not the goal of this paper to arbitrate (scientifically) between these two models. Instead I will simply consider the philosophical implications of both models. Future science may then be able to enlighten us as to which model is, in fact, correct, but whichever it turns out to be we will then have a philosophical framework by which to understand it. Obviously, it is entirely possible that neither model is correct and that a future third model will be the correct one. In that case this paper will hopefully provide a useful framework, and some useful principles, by which to understand the true model, whatever that then turns out to be.

2) Semi-Identical Twins

There is third option ‘midway’ between dizygotic and monozygotic twins, in which two twins share maternal DNA, but have separate paternal DNA. There are two mechanisms put forward to account for this phenomenon. The first is that a single ovum is ‘fertilized’ by two separate sperm. Usually the resulting ‘zygote’ dies very soon after this, but if it survives, either during the initial division of this ovum into two daughter cells, or very early on during cell division, the daughter cells will shed the DNA from one of the sperm resulting in two zygotes with a normal genetic profile, i.e. one set of paternal DNA and one set of maternal DNA. If the daughter cells shed DNA from different sperm the resulting zygotes will have identical maternal DNA, but separate paternal DNA, i.e. they will have paternal DNA from two separate sperm but shared maternal DNA from a single ovum. Put very crudely, one egg is fertilized by two sperm, which then divides into two zygotes with the same maternal DNA but different paternal DNA. The second mechanism is that a single ovum splits before

fertilization and is then fertilized by two separate sperm. Thus, the resulting zygotes/embryos/fetuses have identical maternal DNA but different paternal DNA (Souter V. L., et al. 2007). These sorts of twins have been labeled ‘semi-identical’ (Whitfield, 2007). I shall return to the first mechanism later in this paper, but with regard to the second mechanism (where the ova split before fertilization), although this raises difficult questions about the identity of the ova over time, which this paper may indirectly and implicitly answer, it does not raise any questions of interest to this paper. This is because the ova are fertilized separately and, as a result, the two zygotes are separate from the very beginning. As a result, when it comes to the metaphysical identity of these (semi-identical) twins over time this is no more mysterious than the metaphysical identity of regular (dizygotic) twins over time.

3) Chimeras

Chimerism is “the presence of two genetically distinct cell lines in a [single] organism” (Neng Yu, et al., 2002). There are a number of different mechanisms that result in this phenomenon. However, I will be primarily interested in tetragametic chimerism.

Tetragametic chimerism occurs when non-identical (or semi-identical) twins merge together early on in their development.¹ This results in a single embryo with two separate genetic profiles.

4) A Straightforward Case

I have now given a very simple account of the contemporary scientific descriptions of the various phenomena I will explore in this paper. I will now do three things. First, I will give a metaphysical analysis of standard singleton pregnancies. Second, I will respond to general objections to the Aristotelian metaphysical schema based on contemporary science. Third, I will respond to specific objections to an Aristotelian metaphysical analysis of the early embryo based on findings in modern embryology. I now turn to the metaphysics of these

¹ If Herranz’s new model is correct then presumably, depending upon the philosophical account we give, it is potentially possible for two identical twins to merge together, after initially splitting, resulting in a ‘chimera’, but with a single genetic profile. Whether or not this actually happens is obviously an empirical question and presumably very difficult, if not impossible, to answer.

phenomena. In order to get a clearer grasp of what is going on in these cases, it is worth beginning by examining the metaphysics of a singleton pregnancy.

In my opinion, we ought to begin by answering the question ‘what is a zygote?’² According to the Aristotelian, an organism’s identity is determined by its essence (or nature). Walsh explains, “In Aristotle’s essentialist biology the nature of an organism is manifested as a goal-directed disposition to produce and maintain a living thing capable of fulfilling its vital function in ways characteristic of its kind” (Walsh, 2006, p. 427). This means that an organism’s essence determines the kind of thing it is and the ways it will characteristically behave. The goals to which an organism’s characteristic behaviors and capacities are directed are called its ends. An organism’s essence and ends are closely linked. An organism’s identity (its essence) will dictate what it should and should not do, for example, an oak tree will grow roots and produce acorns because that is part of what it is to be an oak tree. Conversely, we can infer an organism’s identity (its essence) from what it does, for example, a creature that produces honey, is capable of flying and which lives in a hive is certainly honey-beelike if not a full-fledged honey bee (you would need to investigate the creature more closely to work out which). As a result, an organism’s essence and ends are closely linked. What an organism is (its essence) will have an effect on its ends, and thus the its capacities and characteristic behaviors. It is important to note that for Aristotle essences do not exist in a Platonic realm, but instead exist either immanently in a particular thing or abstractedly by an intellect.

Before we proceed any further two important clarifications are needed. First, the emphasis is clearly placed on the organism’s ‘goal-directed disposition’. This means that when determining the nature of an organism it is important not only to consider its current capacities and properties but also its future capacities and properties. As a result, when determining the nature of an organism there may well be ‘more than meets the eye’, and this is particularly the case when examining very young organisms. This is in stark opposition to one of Jeff McMahan’s criticisms of Aristotelian essences. He writes, “For the hylomorphic soul [nature] is the ‘organizing principle’ of the body: it determines how the body *is* organized, not how it might later be organized. The nature of an individual’s soul is therefore manifest in that individual’s present capacities or powers” (McMahan, 2002, p. 13). Here McMahan is simply incorrect, and this can be straightforwardly demonstrated.

² We can then move on to questions about the embryo and fetus.

If an organism's nature solely manifests in "that individual's present capacities or powers" then it would follow that every time an organism manifested a new power, or lost an old power, the original organism had ceased to exist, and a new organism had taken its place. After all, the organism's present capacities and powers have changed and if they are nothing more than a manifestation of that individual's nature then they must have changed because the individual's nature has changed. Given that an organism's identity is grounded in its nature then it follows that the original organism ceased to exist when its nature changed and a new organism, with a new nature, has now taken its place, but this is patently absurd, and no Aristotelian would claim that this is the case. When a child learns to speak (and thus gains a new power) no Aristotelian (and very few, if any, non-Aristotelians) would claim that a new child has now taken the place of the original child. Rather, they would say that the child has developed one of its intrinsic capacities and that this is an entirely natural and good part of that (same) child's development.

The Aristotelian distinction between first and second potencies can clearly explain what has happened here. Aristotle explains this distinction in *De Anima* II.5 (417A-417B) using the examples of arithmetic and grammar. However, here I shall continue with the example of language. A pre-linguistic child has a 'first potency' to speak. When a child then learns to speak but is not currently engaged in speaking (perhaps because they are asleep or attending to some other task) this 'first potency' becomes a 'first act' and a 'second potency' is now present. When a child actually speaks this 'second potency' now becomes a 'second act'. Thus, the 'first potency' relates to that intrinsic disposition that all humans have to learning a language, but which earthworms, plants and rocks all lack. The 'second potency' relates to a particular individual's ability to speak a particular language on a particular occasion.

The distinction between first and second potencies nicely leads on to the distinction between substantial form and accidental form. The essence of an organism consists of its form instantiated in matter.³ Within form we can distinguish between a thing's substantial form and its accidental form. An organism's substantial form makes it what it is, for example, a human being, an elephant, or a honey bee. It will then have certain properties and relations

³ For the sake of completeness, strictly speaking, a material substance's essence (or nature) is its form (the 'what it is') instantiated in matter (the 'what it is made of'). If there are immaterial substances, then their essence is identical to their form. These technicalities go above and beyond what is needed for this paper. As a result, I will largely be using the terms essence, nature and form interchangeably.

that are incidental to this substantial form, which do not define the sort of thing they are. These properties determine the organism's accidental form. An organism's accidental form (consisting of its accidental properties) modifies an already existing thing. Standard examples of accidental properties are things like the organism's location, size and color.

The distinction between substantial form and accidental form means that there is a distinction between two kinds of change. An accidental change involves a substance losing or gaining an accidental form. However, the substance itself persists throughout the change. A substantial change will involve the loss of a substantial form and thus essence and a new one taking its place. As a result, the original organism would cease to exist and a new one would take its place.

In contemporary metaphysics a distinction is made between substance sortals and phase sortals. As Oderberg explains, "a substance sortal is a sortal F, such that an entity which falls under G but then ceases to fall under G necessarily ceases to exist altogether. Hence 'human being' is a substance sortal, since anything that ceases to be a human being ceases to exist altogether. So is 'horse,' 'lion,' 'table,' 'computer,' and so on" (Oderberg, 1997, p. 264).⁴ As should now be obvious, then, a substance sortal roughly corresponds to an Aristotelian substantial form. An Aristotelian substantial form makes something fundamentally what it is, and this explains why it ceases to exist when there is a change in substantial form. Likewise, the most plausible explanation for why a thing cannot survive a change in substance sortal is because the substance sortal to which it belongs makes it fundamentally what it is.

A phase sortal, on the other hand, as Oderberg explains, "is a sortal F, such that an entity which ceases to fall under G does not necessarily cease to exist altogether. 'Sapling' is a phase sortal, so is 'piglet,' 'brown table' (a brown table which was painted white would not cease to exist), 'baby,' 'child,' 'adolescent,' as well as 'captain,' 'president of the USA,' 'parent,' and so on" (Oderberg, 1997, p. 264). It should now be clear that a phase sortal roughly corresponds to an Aristotelian accidental form. A thing can gain or lose an Aristotelian accidental form whilst continuing to exist and whilst remaining fundamentally the same sort of thing. Likewise, a thing can change from one phase sortal to another whilst continuing to exist and whilst remaining fundamentally the same sort of thing. The

⁴ It is worth pointing out that some might object to Oderberg's inclusion of 'computer' in this list since one might not see a computer as a single entity. Rather one might see computers as lots of different substances artificially associated with each other.

correspondence between substantial form and substance sortals, and between accidental form and phase sortals, is not perfect, but it is close enough for our purposes.

The second clarification that is needed is that what is relevant here are not the properties, capacities and dispositions the organism will actually develop. Rather, what are relevant are the properties, capacities and dispositions the organism is directed towards developing. These properties, capacities and dispositions do not have actually to develop in order for us to claim intelligibly that the organism in question is directed towards developing them. To give an example from the world of plants, acorns are directed towards developing into oak trees. Not all acorns develop into oak trees. Many are eaten by squirrels or are killed by frost or drought before they can germinate. However, even in these cases, they are still directed towards developing into oak trees. If the acorns were more fortunate then they would have developed into oak trees and this shows that they are intrinsically directed towards developing into oak trees. This would hold even if all the acorns in the world were eaten by squirrels or killed by frost or drought because the counterfactual that they would have developed into oak trees, if they had survived, still holds.

As has now become clear we cannot simply examine the current properties and capacities of the zygote, instead we need to consider the properties and capacities it is directed towards developing. Towards what is a single-celled zygote directed ultimately? Ultimately, it is directed towards developing a fully functioning, adult human body with all of the capacities and properties that come with that. It will need to go through a variety of stages before it reaches this stage; embryo, fetus, newborn baby, child and adolescent, but from its first moments the zygote is directed towards a gradual and successive development through each of these stages.⁵ This is also true of the embryo and fetus (and indeed baby, child, adolescent and so on).

Recall that “the nature of an organism is manifested as a goal-directed disposition to produce and maintain a living thing capable of fulfilling its vital function in ways characteristic of its kind” (Walsh, 2006, p. 427). It follows from this that the nature of a human zygote is the same as the nature of an adult human being. We are both directed towards producing and maintaining our living bodies, which are capable of fulfilling our vital

⁵ Indeed, as Tollefsen (2006) points out even in the first week the embryo has three recognisable goals. These are, first, to get itself to the uterus. Second, to develop the structures necessary for implantation. Third, and most importantly for our purposes, to preserve its structure *unity*. This, of course, suggests that the embryo is unified and thus ontologically numerically discrete. I will return this issue later in the article.

function in ways characteristic of our kind. The difference between an adult and a zygote is simply that the adult is much further along that chain of development. The adult's brain is already developed, whereas the zygote is in the process of developing its brain. Their nature, however, is the same since they are directed at becoming and remaining the same sort of thing.

There's an obvious objection here. An adult is a fully developed human being. A zygote still has a long way to go before we can say this! Therefore, the zygote cannot yet be said to be a (fully developed) human being, unlike the adult human being. Samuel and Maureen Condic helpfully explain this objection, "Something that is becoming something else is not yet that thing; someone driving to Dallas is not yet in Dallas and a group of cells on their way to becoming human are not yet human" (Condic and Condic, 2018, p. 48).

This sort of objection does not have the teeth it may at first seem to have. It makes the same mistake McMahan made when he wrote, "The nature of an individual's soul is therefore manifest in that individual's present capacities or powers" (McMahan, 2002, p. 13) which was discussed earlier. The error is one of focusing entirely on the organism's current capacities and properties whilst ignoring its future capacities and properties. This myopic analysis of essence risks obliging us to say that every time an organism (such as a child) develops a new capacity or property (such as the ability to speak) a new organism has taken its place and that the old organism has ceased to exist, but this, as explained earlier, is plainly absurd. This shows that as well as taking into account the organism's current properties and capacities we must also take into account the properties and capacities it is internally directed towards developing. If we don't do this, we risk begging the question against the humanity of the zygote by ignoring the very things that demonstrate its humanity, i.e. its future capacities and properties.

When we do this, it becomes clear that the zygote has the same fundamental nature as an adult human. It is simply at a much earlier stage of development. They are as human as we are. The Condicts helpfully explain, the embryo is "a tiny human directing its own growth. This sort of development is clearly seen in other living things. In plants, the development of significant new structures (e.g., the development of bark around the 'trunk' of a seedling or the first formation of fruit on a sapling at several years of age) is not a sign of a new thing being generated (substantial change), but rather of an existing thing developing (accidental change)" (Condic and Condic, 2018, p. 53). Putting this response very simply, we can

acknowledge that the zygote is not fully developed, without having to deny that it is a (very young) human being.

Intuitive support can be found for this analysis of essence by considering the difference between (for example) a dog zygote and a human zygote. Many people think that there is an important difference between a dog zygote and a human zygote. However, if we were to examine the currently existing properties and capacities of a dog zygote and a human zygote the differences would be fairly minor. There would be a genetic variation between the two (although with a great many shared genes), but the size of the cells and the organelles within them would be remarkably similar. Why, then, do many people intuitively think there is an important difference between them? The natural answer is that it is because one will go on to develop the ability to bark, whereas the other will go on to develop the ability to recite poetry. As a result, the difference between the two, which we intuitively feel now, is explained by the capacities and properties they will go on to develop, and this is exactly what the Aristotelian can explain. Obviously, some people may not share this intuition, but a great many people do, and to those who do not share this intuition, one can point them towards the aforementioned metaphysical arguments about the nature of essence and the distinction between substantial and accidental change. The point is that there is some intuitive sense to the Aristotelian schema and this counts in its favor.

5) The Reality of Ends

Many thinkers in contemporary bioethics, and philosophy more generally, are suspicious of the idea of Aristotelian metaphysics. Two particularly common objections based on modern science can be identified. First, there is a general suspicion of teleology. Many thinkers will argue that in light of contemporary science teleological explanations can be discarded and replaced solely by mechanistic-cum-mathematical explanations involving efficient causes only. In this case, isn't talk of final causes and ends explanatory otiose? As a result, shouldn't such concepts be disregarded? Second, when examining one scientific theory in particular, hasn't modern evolutionary biology shown that the concept of Aristotelian essence is plain false? If modern science has shown Aristotelian metaphysics to be false, then any metaphysical analysis of twinning based on Aristotelian metaphysics will also be false. As a result, it is important I respond to these objections. I shall engage with both of them in turn.

Returning to the first criticism, how do we know that ends, and thus essences, are real? Primarily we know that ends are real through an act of observation and then an inference to the best explanation. To continue with our example of an acorn, we all know that if we plant an acorn in the ground and water it, all other things being equal, eventually a sapling will emerge which will in time develop into an oak tree. If acorns were not directed towards growing into oak trees, then why does this happen and why do we expect it to happen? We would have to find some other explanation and, as we shall see, the two most plausible alternative explanations fail.

Appealing to chance is inadequate since chance cannot explain the regularity we observe (for example, of acorns developing into oak trees). If it was chance, then why does it consistently happen in such a regular manner? As Edward Feser explains, “that A generates B in a regular way tells against the connection being a chance one” (Feser, 2014, p. 93) and as Aquinas explains:

“We see that there are things that have no knowledge, like physical bodies, but which act for the sake of an end.

This is clear in that they always, or for the most part, act in the same way, and achieve what is best. This shows that they reach their end not by chance but in virtue of some tendency” (Aquinas, S Th. I q. 2, a 3 c, as translated in C. F. J. Martin, 1997, p. 179).

It is in the very nature of chance that it is unpredictable. If it were predictable then it wouldn't be chance. As a result, if it were entirely down to chance, then we wouldn't expect to see acorns regularly developing into oak trees. It would be just as likely that they would develop into pine tree, or elephants, or that they would spontaneously disappear or explode. As Aristotle explains in book two of the *Physics*, “chance is unstable, since it is impossible for anything which is an effect of chance to happen always or even usually” (Aristotle, 197a25).

We also can't appeal to any rational mind to explain this regularity.⁶ Although Aristotle does use the language of “desire” and “striving” in a non-psychological context;⁷ no Aristotelian (and certainly no modern-day Aristotelian) thinks that everything in the universe has its own unique mind literally “desiring” certain things. Instead, these objects “desire” and

⁶ Let us put Aquinas's teleological argument aside for now at least.

⁷ For example, in *The Eudemian Ethics* (1218a31) he talks about the 'desire' of the eye for sight.

“strive” only analogously to human “striving” and “desiring”. There is no psychological aspect to these ‘desires’; instead they are tendencies towards certain actions and end-states, such as an acorn’s tendency to develop into a mature oak tree.

Further, although human minds may then utilize these tendencies in order to fulfill their goals, the human desire itself does not create this tendency. It merely utilizes an already present tendency. As an example, whilst a person might plant crops in order to feed himself it is not the desire of the person that makes the plants grow. The plants grow of their own nature. The person merely utilizes this tendency. This is clearly the case because plants often do grow entirely without human interference where no mind has any impact or interest in the process itself. As a result, we can’t appeal to human minds to explain the regularity we observe in nature.

Given that both of these alternative explanations have failed we are forced to acknowledge the reality of ends. Acorns, quite clearly, are directed towards growing into oak trees. Given that an organism’s essence and ends are inextricably linked we are therefore forced to acknowledge the reality of essence.

6) Evolution and Essence

Turning now to the second common objection, often it is thought that the theory of evolution might in some way pose problems for the idea of essence. For example, Rosalind Hursthouse writes, “I accept that, although Aristotle was not the essentialist that Plato was, he certainly did believe some things about species essences which evolutionary biology undercuts” (Hursthouse, 2012, p. 170). Quite why she thinks that evolutionary biology undermines Aristotelian essentialism is unclear and she does not expand in great detail. Denis Walsh also highlights that in modern philosophy of biology the concept of essence has fallen out of fashion: “There is a consensus that essentialism has no part to play in biology” (Walsh, 2006, p. 425).

There have been a number of arguments put forward for why evolution is incompatible with essentialism. One of the most influential arguments says that the classification of organisms into essentialist kinds is incompatible with evolution. This is because species change over time and begin to exist and cease to exist. They are not fixed but instead are fluid. According to these critics, essentialist kinds, on the other hand, are fixed

and unchanging. Ernst Mayr was one of the most prominent advocates of this line of argumentation. He writes:

“According to [typological thinking], there are a limited number of fixed, unchangeable ‘ideas’ underlying the observed variability, with the *eidos* (idea) being the only thing that is fixed and real, while the observed variability has no more reality than the shadows of an object on a cave wall ... The discontinuities between these natural ‘ideas’ (types), it was believed, account for the frequency of gaps in nature ... Since there is no gradation between types, gradual evolution is basically a logical impossibility for the typologist. Evolution, if it occurs at all, has to proceed in steps or jumps. (Mayr, 1959, pp. 28-29)

The target here is what Mayr calls ‘typological essentialism’ and this simply doesn’t apply to Aristotelian essentialism. At its most extreme, typological essentialism is much closer to a form of Platonic realism about universals than it is to Aristotelian essentialism. According to Platonic realism, there is a single, transcendent, eternal and unchanging form for each species (potentially existing in a Platonic ‘realm of forms’). Each individual organism, here on Earth, either does or does not partake (imperfectly) in this form. However, according to evolution each currently existing species slowly came into existence from earlier slightly different species and, if there are appropriate evolutionary pressures, each species may well gradually change into another species that does not currently exist. There will be innumerable ‘transitional’ individuals who could be considered members of either the ancestral or descendent species. Further, since in the past, species did exist which do not exist now, the species that currently exist may well not exist in the distant future with entirely new species replacing them. As a result, the two do not mesh together at all. Evolution suggests that species are fluid, impermanent and ever-changing, whereas Platonic realism suggests that species (or at least their forms) are eternal and unchanging.⁸

On the other hand, Aristotelian essentialism does not see a species’ essence as transcendent or fixed. Instead, they are goal-directed capacities instantiated in each individual organism. As a result, there is no reason, under Aristotle’s schema, to think that natures couldn’t change over time. Walsh points out that under the Aristotelian scheme “Individual organisms may well vary in their formal and material natures, in such a way that over time some variants become more common than others” (Walsh, 2006, p. 431). Thus, there is no

⁸ For a contemporary defence of typological essentialism see Lewens (2009).

reason to think that essences couldn't gradually change over time and across generations. As a result, this line of anti-essentialist argument simply misses the point when it comes to Aristotelian essentialism (although it may pose more serious problems for a more extreme Platonic realism about form, essence and universals).

7) Baby Teeth and the Trophoctoderm

We have now given a metaphysical analysis of the human zygote and have seen that the nature of the zygote is that of a human being. We have also examined some common objections to Aristotelian metaphysics and have found them to be wanting. As a result, we can conclude that human zygotes have the same nature as adult human beings. We know this because they are directed towards the development of the same capacities and properties as adult human beings. It follows that their nature (or essence) is the same as adult human beings, and thus they are as human as you and me. We shall now examine some objections to this based on modern embryology.

The first objection I shall consider is based on the fact that before day five post-conception the inner cell mass (ICM) and trophoctoderm are undifferentiated. After day five they differentiate with the ICM eventually forming the embryo proper and the trophoctoderm forming the placenta. Using this observation some have argued that before day five the 'embryo' cannot be considered a human being. As Shoemaker explains:

“Consider, for example, what happens at around five days after fertilization, when certain cells separate off from the ICM to form the trophoctoderm. The entire collection, including the outer layer, still falls under the rubric of 'embryo' ... but it is only the cells of the ICM whose descendants will form a fetus and then an infant. Are the cells of the trophoctoderm, which are synchronically unified with the cells of the ICM at this time as an embryo, also unified as part of a single human being via the soul? If so, then the shedding of the placenta as afterbirth (and its eventual casual destruction) would seem to have heretofore unrecognized moral implications, insofar as it would involve the destruction of at least part of a human being. Surely this cannot be right, though, and as far as I know, no one holds that the placenta is part of a human being. If not, then the ontological object to be ensouled is not the embryo but the ICM. But the ICM does not come into existence until around five days post-conception” (Shoemaker, 2005, p. 61).

This objection strikes me as particularly weak and this can be seen by examining the phenomenon of baby teeth. Nobody doubts that we can identify a toddler (for example) and clearly demarcate its physical boundaries because it has baby teeth that will be discarded later in life. In this situation we, quite rightly, view the teeth as being part of the toddler, albeit part of the toddler that will be discarded at a later date. It seems to me that in an almost identical way, prior to birth, we ought to view the placenta as part of the fetus, albeit a part of the fetus that will be discarded at a later date. If the placenta is considered part of the fetus then the fact that prior to day five post-conception the trophoctoderm and ICM are undifferentiated is simply irrelevant. It would have no more relevance than the fact that prior to a certain date the fetus's other organs have not yet differentiated from each other. The fact that the heart and lungs have not yet differentiated from the rest of the body, for example, prior to ten weeks does nothing to show there isn't a single discrete (albeit very young and undeveloped) human being present prior to that date.

Now, Shoemaker is right to say that, at least in the medical world, the placenta is not considered part of the fetus. However, this is because medics are primarily interested in the persistence and development of the child first inside and then outside the womb. As a result, it makes sense for them to distinguish between the placenta and embryo or fetus on medical grounds in the same way it might make sense for a dentist to distinguish between a child's baby teeth and adult teeth. However, to draw any metaphysical conclusions from this seems simply wrong-headed. As Oderberg explains, "there is nothing improper, ontologically speaking, from using the term [fetus/embryo] to refer to the child along with its placenta, umbilical cord, and so on: we might do so in order to distinguish it, with all its parts, from the mother. The former use is more common, though, since we are usually more interested in the persistence and development of the child inside and outside the womb; for which purpose we use terms such as 'fetus' and 'embryo' to refer to everything that is not discarded at birth, namely the body of the child minus that parts needed only for gestation. This we can call the 'embryo/fetus proper' in order to clarify what it is we are referring to" (Oderberg, 2008, p. 265). As a result, it seems to me that this objection has limited, if any, weight.

8) The Irrelevancy of Totipotency

Some critics have argued that zygotes and early embryos can't have the same nature as adult human beings because there is an indefinite number of human beings present during early

pregnancy, and they argue for this on the basis of totipotency. As the Condicts explain, “Typically, ‘totipotent’ refers to those cells capable of producing *all* the cell types of the embryo, *including* those cell types that make up the extra-embryonic organs of the embryo; namely, the placenta, amnion, and chorion.” (Condic and Condic, 2018, pp. 82-82).⁹ It is this totipotency that allows for the possibility of identical twins. That being said, a single totipotent cell does not have the ability to form a new embryo. As the Condicts explain:

“However, though totipotent cells may produce all cell types, individual totipotent cells (other than the zygote) do not appear to be capable of producing an organized or complete body. Recent research with primates suggests that at least two totipotent cells are required to produce the complete animal ... To distinguish, then, between totipotent cells, on the one hand, and those totipotent cells that can actually form a complete body, the term ‘plenipotent’ has been proposed. The zygote would be totipotent according to the proposed usage because it has the ability to form a complete body. ‘Plenipotent’ would refer to cells capable of forming all the tissue types found in the embryo – including the placenta and embryonic membranes – but not the complete body as an organized, functional whole” (Condic and Condic, 2018, pp. 83-84).

For the sake of simplicity, I will simply talk about totipotency unless the distinction becomes important. The point, for our purposes, is that early fetuses and embryos can split into two (or more) separate organisms.

Some thinkers have argued that totipotency challenges the idea that there is a single human organism, indeed any human organism at all, present from the moment of conception. As Ford explains:

“Once we assume that the zygote is a human individual because it has the natural active potential to develop into an adult we begin to run into difficulties. The same zygote would also have the natural active potential to develop into two human individuals by the same criteria. We could legitimately ask whether the zygote itself would be one or two human individuals. It would seem absurd to

⁹ It is perhaps worth distinguishing totipotent cells from pluripotent cells which “can produce only the cell types eventually found in the post-natal body. Pluripotent cells lack the ability for form the extra-embryonic organs such as the placenta. Embryonic stem cells are pluripotent in this sense” (Condic and Condic, 2018, p. 83). Pluripotent cells are more valuable for medical research and it is these sorts of cells which are the subject of contemporary debates about ‘stem cells.’

suggest that at the same time it could both be one and more than one human individual, granted that each must be a distinct ontological individual” (Ford, 1988, p. 120).

Put another way, if we say that a zygote is a human individual because it can develop into a human individual, then because a zygote can develop into an indeterminate number of human individuals the zygote must be an indeterminate number of human individuals. However, human individuals are ontologically numerically discrete, and thus zygotes can't be human individuals since they are not ontologically numerically discrete.¹⁰ Due to considerations like this many, such as Steinbock, have concluded that “the chance of twinning ... makes it impossible to say that at fertilization there exists a unique human being” (Steinbock, 1992, p. 50). How are we to respond to this?¹¹

Let's begin by examining what implications this ability has for singleton pregnancies. On this analysis, there are none. Why should the fact that a single zygote can split into two separate organisms prevent there being a single organism present when it hasn't split? On this analysis, it has the potential to split into two organisms, but this doesn't prevent there being only a single organism currently present. As Lu helpfully explains, “This argument has always struck me as rather strange. Why should it be true that just because there is some *possibility* that an individual substance can be split that there can be no ontological continuity in the case in which it *does not actually* split? If I have a banana, it is possible to make a banana split. However, it is surely strange to claim that because my banana can *possibly* be cut in two, it is not the *same* banana if it is not actually divided. It seems to me that the mere possibility that a substance can divide is insufficient to conclude that there is no diachronic identity when in fact it *does not* divide” (Lu, 2013, pp. 106-107). As Munthe explains, “The embryo may be a unique human being which, when twinning occurs, divides into two other unique human beings, and the undivided (divisible) embryo may be a unique human being that could be (but is in fact not) extinguished through division” (Munthe, 2001, p. 395).

¹⁰ See also Kuhse and Singer's 'Individuals, Humans and Persons: The Issue of Moral Status' in *Embryo Experimentation* (Kuhse and Singer, 1990, p. 66).

¹¹ One philosophically straightforward response would be to deny that human embryonic cells are totipotent. This strategy has been adopted by Koch-Hershenov (2006). She argues that there is insufficient evidence for human totipotency. I commend this strategy but worry that it will always be provisional and dependent upon the next scientific finding. As a result, I am inclined to assume that human embryonic cells are totipotent and to then consider the implications of this. However, if the reader is interested, I will include details of Koch-Hershenov's (2006) paper in the bibliography.

There is an obvious objection here based on Aristotelian metaphysics. Earlier I highlighted that when identifying the essence of an organism, it is important to pay attention not only to its current capacities and properties, but also to its future capacities and properties. If the zygote has the capacity to develop into either a single organism or multiple organisms, then surely numerical ontological indeterminacy is as much a part of its essence as anything else. Therefore, perhaps it is false to say that it is a single discrete organism because numerical ontological indeterminacy is part of its essence.

I would respond to this in two ways. First, the zygote, due to its totipotency, quite clearly has the potential to split into multiple organisms, but it does not follow that splitting into multiple organisms is one of its ends. The fact that something *could possibly* happen to something does not mean that it will be one of its ends; more is needed. To give an example, trees have the potential to be chopped down and burnt for warmth (or carved into wooden beams and made into a house, and so on), but it seems a far stretch to say that this is one of the *ends* of trees.¹² Trees do not exist *in order* that we can chop them down and burn them. They exist entirely for their own sake. It just so happens we can use them for our purposes (of keeping warm, or of building houses, and so on) and as a result there is a possibility that this will happen to them (that they will be chopped down and burnt, or made into a house, and so on). In the same way, just because a zygote or embryo has the potential to split into two or more organisms it does not follow that numerical ontological indeterminacy is part of the essence of the zygote or embryo.

Second, relatedly, the primary reason that the cells of an embryo are totipotent is because it is this ability that allows them to differentiate and to develop into the various different organs needed later on in the organism's development. The fact that it *also* allows identical twins to occur is entirely accidental to this. Thus, the end of totipotent cells, *qua* totipotency, is to differentiate into the different types of cell that eventually form the organs of the organism of which they are a part. It is *not* to form twins. As a result, there is simply no reason to think that numerical ontological indeterminacy is in any way part of the essence of zygotes and fetuses. The fact that they can split into twins is entirely accidental to their essence.

¹² Although, admittedly, it would be *the end* of the tree, but in quite a different sense. This is little more than a play on words.

This discussion of teleology (goals) nicely leads us into an objection raised by Jason Morris. Morris objects to appeals to teleology to justify the moral status (and individuality) of embryos because “Attributing ‘goals’ to a cell to buttress an argument for its moral status is tendentious at best, in any case. One could attribute goals and concerted action to a white blood cell at least as compellingly as for a zygote ... Arguments based on goals, different tissue types, or coordination of development all fail to distinguish individuals either from collections or from parts of individuals” (Morris, 2012, pp. 346-347). The problem with this objection is that it ignores the *types* of goals that apply to embryos and white blood cells (for example). As a result, it simply ignores half the answer. It is not just the fact that embryos exhibit teleology. It is the fact that they exhibit the exact same teleology as adult human beings! White blood cells (for example) are directed towards existing as part of a human being and towards contributing to the health and continued existence of that human being. An embryo, on the other hand, is ultimately directed towards developing the same capacities and properties as adult human beings. It follows that their nature (or essence) is the same as adult human beings. In this sense white blood cells (for example) and embryos couldn’t be more different! Further, as we have seen, the end of totipotent cells, *qua* totipotency, is to differentiate into the different types of cells that eventually form the organs of the organism of which they are a part. It is not to form twins. As a result, this objection has limited, if any, weight.

To bring these responses together, fetuses and embryos are totipotent and as a result there is the possibility that they could split and become separate organisms. However, this is accidental to their essence. It is not one of their ends because it is not “a goal-directed disposition to produce and maintain a living thing capable of fulfilling its vital function in ways characteristic of its kind” (Walsh, 2006, p. 427). Human beings are not *characteristically* identical twins, nor are they disadvantaged or less capable because of this. Most human zygotes and embryos, totipotent cells and all, will develop into single organisms; indeed, each one is already a single (very small) organism. They will continue to develop into single organisms (rather than multiple organisms) in part because they are already single organisms. As a result, there is simply no reason to think that numerical ontological indeterminacy is part of the essence of a zygote or embryo. Therefore, totipotency is simply irrelevant when considering the metaphysical status of a normal zygote or embryo. There is one organism present. There is the possibility that it might split into two organisms,

but until that happens there is only one organism present. What about when twinning does occur? It is to this question that we now turn.

9) Getting from One to Two

In order to answer this question, let's begin by looking at Herranz's model (Herranz, 2013). According to Herranz's model "All MZ twinning is the result of the first zygotic division. In other words, in the case of MZ twinning, the first cleavage division of the fertilized egg, instead of giving origin to two blastomeres, generates twin zygotes" (Herranz, 2013, p. 33). There are now two possibilities. The first is that there is something about the fertilized egg that means that it is predisposed to divide into two twin zygotes. What it is that would make the original fertilized egg predisposed to divide into two twin zygotes is something empirical science would have to answer. Perhaps the sperm and the egg fuse in an unusual manner, or perhaps the egg (or sperm) is malformed in some manner prior to fusion, or perhaps there is some genetic 'quirk' that predisposes the fertilized egg to divide into twin zygotes.¹³

Whatever the reason, in this situation, the fertilized egg would not be a 'true' zygote prior to splitting. Why is this the case? Well, as we've seen normal fertilized eggs are not disposed towards dividing into twin zygotes. They are directed towards the development of a single organism. As a result, they are ontologically discrete in a way that the original MZ fertilized egg is not. The original MZ fertilized egg is thus numerically ontologically indeterminate and this prevents it from counting as a 'true' zygote (which are ontologically discrete). In this case there is never a *single* zygote/human being present; instead there is a single original MZ fertilized egg (which is not a human being), which divides into *two* separate zygotes/human beings. The moment there are any 'true' zygotes/human beings present there are two of them.

The other option is that there is nothing that predisposes the original fertilized egg to divide into twin zygotes.¹⁴ Here the original fertilized egg divides into twin zygotes merely by chance.¹⁵ In this case, the original fertilized egg is a 'true' zygote. Thus, we start with one

¹³ Ultimately, this is a question for empirical science to answer.

¹⁴ Future medical research may vindicate or rule out this possibility in some or all cases of twinning. As a result, once again, this is a question for empirical science to answer.

¹⁵ Presumably there must be some 'cause' or 'reason' (in some sense of the word) which explains why some fertilized eggs divide into two blastomeres and others into twin zygotes. However, it still makes sense to ask whether this 'cause' or 'reason' is intrinsic or extrinsic to the fertilized egg. If it is intrinsic, then the first possibility will be the case. If it is extrinsic, then this second possibility will be the case. If it is extrinsic, then there is nothing about the fertilized egg itself which predisposes it towards dividing into twin zygotes, even though there will be an 'explanation' of some sort. This obviously raises questions about the metaphysics of

zygote/human being and end up with two zygotes/human beings and there are only two plausible ways this could happen.¹⁶

One plausible way this could happen is that a new one is added to the original. In this case, the original zygote/human being remains and a new one ‘buds off’. The other plausible way this could happen would be that the original one ceases to exist, and two new ones take its place. In this case, the original zygote/human being ceases to exist upon division and two new zygotes/human beings take its place.

These are the same possibilities that face us when considering the traditional model of MZ twinning according to which twinning takes place anytime between the initial cell division right up until the appearance of the primitive streak at 14 days (or later in the case of conjoined twins). Either the original survives the split, or it does not.

From an epistemic perspective it may well be very difficult, if not impossible, to determine whether the original survives the split. Empirical science may give us some reason to think that the one of the twins is the original, although this will still require careful philosophical analysis, or it may not.¹⁷ However, none of this changes the metaphysical fact that either the original survives the split, or it does not. These are simply the only options. Further, the epistemic difficulty in determining whether or not the original survives certainly does nothing to undermine the (metaphysical) idea that there are a determinate number of human beings present at every stage during human pregnancy. As Helen Watt explains, “It may indeed be impossible to *know* in the case of twinning which embryo, if either is the original individual that budded to create a new embryo and which is the ‘budded off’ individual created” and that “In some cases, it may be clearer that one particular individual has budded to produce another while surviving the process ... this is not unique to natural twinning: any adult could theoretically be cloned if his or her cells were taken and used to produce new human beings. That would not cast doubt on the individuality of the adult, either before or after the process: the adult would simply have given rise to clone ‘offspring’

causation and the principle of sufficient reason which we do not have space to answer here, but hopefully my point is clear enough.

¹⁶ Technically, there are an infinite number of mathematical ways of getting from one to two, but in this scenario, as we shall see, there are only two plausible ways it could happen.

¹⁷ There is also no reason to rule out the possibility that different instances should be interpreted in different ways depending upon the empirical details. It may be the case that twinning occurs as a result of many different mechanisms in which case different cases may need to be interpreted differently. Alternatively, it may be the case that all twinning occurs in a very similar way in which case perhaps it is best to interpret them all in the same way. I leave this question to future scientists and philosophers.

in an asexual way. And even if the adult was destroyed in the course of breaking his or her body into clonable cells, that would admittedly end the adult's life, but would not cast doubt on his or her individuality before that point" (Watt, 2016, p. 18).¹⁸

10) Semi-Identical Twins and Chimeras

We now turn to semi-identical twins and chimeras. Let us begin by discussing semi-identical twins. One of the models involves the egg dividing into two prior to insemination. For our purposes this model is uninteresting since the two semi-identical twins are separate from the moment of conception. The other model involves two separate sperm inseminating a single ovum. Upon the initial division of this ovum into two daughter cells, or very early on during cell division, the daughter cells will shed the DNA from one of the sperm. The result is two zygotes with a normal genetic profile, with identical maternal DNA but (potentially) different paternal DNA. As a result, we obviously end up with two embryos. The question then becomes: what is the status of the original 'doubly' fertilized ovum prior to division? Is this a human organism? And if so, does it cease to exist upon division, or does it continue to exist as one of the semi-identical twins?

I think the best interpretation here is that the 'doubly' fertilized ovum is not a zygote/human being. This is because it does not have a conventional genetic profile and, more importantly, it is not intrinsically directed towards developing a single, fully functioning, adult human body with all of the capacities and properties that come with that. As a result, it is neither ontologically numerically discrete, nor does it display the appropriate teleology (ends) that one would expect to see if it had the form (or nature) of humanity. As a result, this 'doubly' fertilized ovum is not a zygote or human organism. Two zygotes/human organisms then come into existence upon the division of this ovum.

As for chimeras,¹⁹ in many ways, chimeras are simply the reverse of identical twinning. We start with two zygotes/embryos/human beings and we end with one. Again, there are only two (plausible) options. Either one of the originals survives and simply

¹⁸ Lee, Tollefsen and George (2014) make a similar point (p. 496).

¹⁹ Similar to Koch-Hershenov's response to totipotency, one straightforward response to chimeras (and the possibility of fusion) would be to deny that it happens and that it is possible. This is the approach taken by her (and her co-author) in Hershenov and Koch-Hershenov (2006). Once again, however, I worry that this approach will always be provisional and dependent upon the next scientific finding. Further, it strikes me that Neng Yu, et al. (2002) have done a good job in establishing the reality of this phenomena. However, once again, for the interested reader I will include a reference to Hershenov and Koch-Hershenov (2006) in the bibliography.

‘absorbs’ the other zygote/embryo/human being, which ceases to exist, or they both cease to exist, and a new embryo takes their place. Currently, it may well be the case that epistemologically there is very little reason to favor one option over the other, but this doesn’t change the metaphysical fact that there are a finite number of plausible metaphysical options, all of which involve a determinate number of human beings being present at every stage during human pregnancy. Future empirical science may then provide evidence to support one interpretation over another, but this does nothing to undermine my point.²⁰

11) Conclusion

Bringing everything together, we can see that none of the findings of modern embryology pose any problems for the Aristotelian. For each of the various phenomena identified there are ways of interpreting them in accordance with the Aristotelian metaphysical schema whilst holding on to the idea that there is a determinate number of human beings present at every stage during human pregnancy.

There are two ways of interpreting the phenomenon of MZ twins. If there is something intrinsic to the original fertilized egg which predisposes it towards division into twins then the best interpretation is that this fertilized egg is not a ‘true’ zygote, but that two (‘true’) zygotes/human beings come into existence upon the division of this fertilized egg. If there is nothing intrinsic to the original zygote that predisposes it towards division into twins, then we start with one zygote/human being and after division we have two. Either the original survives as one of the two twins, or it does not. This question, from an epistemic perspective, may be very tricky, if not impossible, to answer. If it can be answered, then it may well need answering on a case-by-case basis based on empirical evidence. However, none of this detracts from the point that there are always a determinate number of zygotes/human beings present at every stage of pregnancy.

When considering semi-identical twins, the ‘doubly’ fertilized egg should not be considered a ‘true’ zygote/human being. The ‘true’ zygotes/human beings come into

²⁰ For the sake of clarity, there’s no reason to think that one interpretation will hold for all chimeras (or twins). It may well be the case that some cases of chimerism involve ‘absorption’, with one of the originals surviving, and that others involve a new embryo emerging as a fusion of the two originals, with neither of the originals surviving. Alternatively, future science may suggest that all cases involve a near identical process in which case perhaps all cases should be interpreted in the same way. I leave this to future scientists and philosophers to settle.

existence upon the division of this original 'doubly' fertilized egg. Once again, there is always a determinate number of human beings present at every stage of the pregnancy.

When considering chimeras, these are simply the reverse of identical twins. You start with two zygotes/human beings and you end with one. Either one of the originals survives as the hybrid, or both cease to exist and a new one takes their place. This question, from an epistemic perspective, may be very tricky if not impossible to answer. If it can be answered, then it may well need answering on a case-by-case basis based on empirical evidence. However, none of this detracts from the point that there are always a determinate number of human beings present at every stage of pregnancy.

To conclude, none of these phenomena poses any difficulties for the Aristotelian. We can easily hold on to the idea that there are a determinate number of human beings present at every stage of a human pregnancy. As a result, objections to the humanity of zygotes based on totipotency and twinning fail.

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