Sixteen Days

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Abstract

When does a human being begin to exist? We argue that it is possible, through a combination of biological fact and philosophical analysis, to provide a definitive answer to this question. We lay down a set of conditions for being a human being, and we determine when, in the course of normal fetal development, these conditions are first satisfied. Issues dealt with along the way include: modes of substance-formation, twinning, the nature of the intra-uterine environment, and the nature of the relation between fetus and mother (connection, parthood, dependence).

I. Introduction

We shall help ourselves in what follows to the Danish term 'foster,' which refers in neutral fashion to the human zygote, embryo, or fetus at different stages of development. 'Foster' should be understood by analogy with terms like 'president' or 'customer'. It is a definite functional description meaning: organic individual possessing a full set of chromosomes and inhabiting the fallopian tube, uterus or uterine lining. The term 'individual' (and indeed the term 'inhabiting') will be subjected to clarification in the course of what follows. For the moment we note only that we shall be focusing primarily on the sense of individuality that is peculiar to higher organisms like ourselves. This will mean that we will in the end advance a usage of the term 'individual' which will make 'human organism', 'human being' and 'human individual' synonymous.[1] We note also that human life can be present in principle even in the absence of any human individual—for example in the case of living cells taken from human beings for purposes of experimentation.

What follows is an exercise in ontology, and clearly no conclusions of an ethical sort can be drawn directly from the answer to any ontological question. Lest the reader thinks that it is possible to draw such conclusions from our answer to the question as to when a human being begins to exist, we note (1) that there are many situations in which it is justified to kill a human being (self-defense is one such case), and also (2) that establishing when a human being begins to exist does not in and of itself establish when rights or other morally relevant attributes can begin to be assigned to that being. It seems to us, however, to be equally clear that an answer to the question as to when a human organism begins to exist can be of some help in settling the

[1] Compare Wilson 1999 and section IX below.

difficult problems which arise in connection with the issue of abortion and embryonic stem cell experimentation.

II. The Marks of Substance

At what stage is the foster first transtemporally identical to the human being as it exists after birth? Is there a point in time at which a human being begins to exist, analogous to the point in time at which death occurs? In order to answer these questions we will need to take empirical details into account. It matters, for example, whether or not the cells constituting the early foster are a mere collection (as a heap of grains of sand is a mere collection) or whether they form some sort of causal unity. We shall need also to take into account certain technical concepts of ontology. This is because, while it is sufficient to use our unaided common sense in order to establish that, for example, mature adults are human beings, our common-sense concepts are found wanting when it comes to answering the more difficult question concerning when human beings begin (or cease) to exist. The concepts we shall need to make them fit for this purpose are concepts such as: boundary and connection, part and whole, dependence and independence. Our strategy will be to use such concepts to establish the ontology of the process by which human beings are formed.

The conclusion we reach is not original. Arguments in its favor have been presented most extensively by Ford.[2] Ford himself however focuses his argument almost exclusively on the single factor of totipotentiality, and we shall see that several other factors are involved, some of which are of equal or indeed greater importance in the formulation of a genuinely conclusive argument. Nowhere in the literature has a general ontological framework been provided that is sufficiently refined that it can cope with all of these factors together. It is this general ontological framework that is presented in what follows.

We shall here assume that human beings and other organic individuals are three-dimensional spatially extended entities which exist *in toto* at any time at which they exist at all.[3] Each human being or other higher organism is therefore a substance in Aristotle's sense, which means that under normal circumstances it satisfies the following six conditions:[4]

> *1*. Each substance is a bearer of change. Substances undergo processes and they manifest contrary qualities at different times. (John is sometimes warmer, sometimes cooler.)
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> *2*. Each substance satisfies the condition that it cannot continue to exist and become a different substance. Thus, it remains numerically one and the same substance from the beginning to the end of its existence, even when undergoing alterations of a range of different sorts. (John is the same substance as he was this morning, even though his temperature has changed.)
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> *3*. Each substance is extended in space, and thus it has spatial parts. A substance can gain and lose some of its spatial parts and yet still preserve its identity. (The spatial parts of John are, for example, his arms and legs, his cells and molecules.)

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[2] Ford (1988).

[3] We do not dismiss the arguments of those philosophers who favor a four-dimensionalist conception according to which organic individuals would have not only spatial but also temporal parts or phases. It is conceivable, however, that the crucial stepping-stones in our argument could be reformulated in such a way as to be consistent also with a view along four-dimensionalist lines.

[4] Compare Novak (1963) and Smith (1997).

4. Each substance possesses its own complete, connected external boundary—analogous to the surface of a sphere or torus—which divides its interior from its exterior and at the same time separates it spatially from other substances. Substances are distinguished, through this separation, from the undetached parts of substances. The latter can become substances, but only through becoming detached, when they acquire completed, connected external boundaries of their own.

5. Each substance is connected in the sense that its parts are not separated from each other by spatial gaps. (Substances are thereby distinguished from heaps or aggregates of substances, such as the jazz band in which John plays of an evening.)

6. Each substance is an independent entity in the sense that it does not require the existence of any other entity in order to exist (in the way in which, for example, smiles or blushes or headaches require other specific entities as their bearers or carriers).

That these conditions are satisfied by adult human beings who are the products of normal fetal development appears to be established by common sense. Some commentary is nonetheless required in relation to conditions *4.* through *6.* The term 'boundary,' as used in *4.*, refers to an abrupt threshold between the matter of normally lower density (air or water) in the space surrounding the individual and the matter in the individual's interior. The unifying and separating role of boundaries is thus consistent with the fact that, when we examine such boundaries more closely, we find that they need not be constituted via any continuous physical envelope. This means also that the term 'interior' as employed in *4.* is problematic, since the boundaries of organic individuals like ourselves make us analogous not to spheres but rather to tubes or hollow cylinders. Part of John's boundary is on what we ordinarily call the inside of his body. Thus if John swallows his wedding ring then we might say the wedding ring is *in* John's stomach, but it is strictly (topologically) speaking external to John. Condition *4.* will imply, too, that a Siamese twin is not a substance, since it does not possess its own complete boundary that serves to separate it spatially from other material entities. 'Separation' here is defined in terms of the notion of boundary, and will be subject to further elucidation below. The bacteria in your gut are separate from you in the sense that you and they have no boundaries in common. Each Siamese twin, in contrast, shares a part of its boundary with its partner. If Siamese twins are able to be separated by surgical means, then each twin becomes on separation a substance in its own right.

We can throw further light on the notion of separation by considering what happens when an amoeba splits into two. The matter of the amoeba is partitioned now as one substance, now as two. When we examine such an occurrence on the microscopic level we will be confronted in the immediate area of separation by a rapid but gradual thinning out of matter. At some point in this process, however, we see a new density threshold pattern becoming established almost instantaneously. There is then a very brief interval, as the thinning out of matter comes to an end, which marks the division between the two distinct partitions into substances of the same underlying parcel of matter. (Compare the way in which two drops of water become one almost instantaneously when they merge together.) We shall call such a repartitioning event a *substantial change.*

III. Organisms as Causal Systems

The six criteria listed above are not, as yet, sufficient for our purposes. Inspection reveals that they are satisfied not only by organic individuals but also by bounded chunks of non-living matter (for example by planets or footballs). They are even satisfied by the whole consisting of a box together with a set of wooden bricks which have been placed inside it. And they are satisfied by a whole consisting of a sealed aquarium inside which various large and small fish are swimming. Moreover, the question whether or not the conditions above are satisfied does not depend on how tight the seal is. The seal of a football is permeable by water; each human being sweats and thereby separates salt and water through the skin.

A single living cell is a substance in the sense determined by our conditions: it has a more or less permeable membrane surrounding a nucleus, mitochondria, endoplasmic reticulum and so on, all of which float in an intracellular fluid. To capture how cells, like human beings and other organisms, are distinguished from wooden boxes, blocks of ice and similar chunks of non-living matter, we need to introduce the concept of a *unified causal system that is relatively isolated from its surroundings*.

In order for an entity to constitute a relatively isolated causal system in the sense here at issue it must be the case that:

> *7.* The external boundary of the entity is established via a physical covering or membrane which extends continuously across all or almost all of its surface (‘almost all’ because it typically contains small apertures—such as pores, mouth or nostrils—which allow interchange of substances such as air and food between interior and exterior).
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> *8.* The events transpiring within the entity are subject to a division between those whose characteristic magnitudes (of temperature, pressure, chemical composition and so on) fall within a certain spectrum of allowed values and those where corresponding magnitudes fall outside this spectrum. The former fall within a restricted family of types of sequences of events (for example digestion), which are often cyclically repeated. The latter are distinguished by the fact that they will, in cumulation, lead to the entity’s ceasing to exist.
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> *9.* The external membrane or covering serves as a shield to protect the entity from those causal influences deriving from its exterior which are likely to give rise to events which are outside its spectrum of allowed values.
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> *10.* The entity contains within itself its own mechanisms which are able to maintain (or, in cases of disturbance, to reestablish) sequences of events falling within the spectrum of allowed values. The entity also contains within itself mechanisms for reconstituting or replacing its external membrane or covering in case of damage.

The two concepts – of substance and relatively isolated causal system – are to a degree independent of each other. A block of ice is a substance, but it is not a relatively isolated causal system. An orbiting space-ship, with its sophisticated mechanisms for self-repair, is both a substance and a causally isolated system. An amoeba, towards the end of a process of fission, is one substance (by the connected external boundary criterion (*4.*)), but two causally isolated systems. It becomes two substances almost instantaneously, as we saw. It becomes two causally isolated systems gradually, via a continuous series of changes. Thus the concept of a relatively

isolated causal system is instantiated to different degrees by different entities. Leaving aside very rapid phases of transition, however, the concept of substance is instantiated either fully or not at all.

IV. The Hierarchical Structure of the Organism

The idea of a relatively isolated system goes back at least to Spinoza, who in his *Ethics* (13-16) characterizes a 'union of parts' as being such that it can become greater or smaller and yet retain its nature and its identity. This will be so, Spinoza tells us, if its parts maintain their proportions and mutual communication. Spinoza's preferred example for such a union of parts is the human body. He points out that the human body is hierarchically structured, which means that it contains a number of parts which themselves contain parts, and so forth. Among contemporary philosophers, the concept of a relatively isolated causal system has been treated of most extensively by the Polish ontologist Roman Ingarden, who points out that organisms, in order to be able to sustain themselves effectively as identical through time, must be at least in some respects "bounded off from the surrounding world and partially isolated or, better, shielded from it."[5]

Each complex multi-cellular organism is a relatively isolated causal system which is organized in modular fashion in such a way as to contain within itself numerous further relatively isolated causal systems on successively lower levels. The latter are hierarchically ordered and at the same time both partially interconnected (they collaborate in their functioning) and also partially segregated from each other via coverings or membranes which protect their interiors from certain external influences and also allow other kinds of influences and substances to pass through them. The whole body, too, "is surrounded by a well-defined enclosure—for man this is the skin, for the majority of animals—the hide."[6] The skin or hide is itself a complex organ which is composed of many layers and has many functions in the life-process, precisely because it forms the boundary between the body and the external world. Thus it is a permeable membrane, which participates in the expulsion of water and waste-products.

Another example of a relatively isolated causal system within the body is the alimentary system which, thanks to its walls, isolates ingested nutrients from other parts of the body in such a way as to allow the initial digestive processes to proceed. Its permeable membranes then make possible a selective migration of the chemical products of these processes through the walls and into the blood. The heart and lungs, too, are separated from each other by appropriately constructed membranes (pericardium, pleura), which shield the processes occurring within them from outside influences.

These systems are not absolutely closed off from each other. Rather, again, they are partially open and partially shielded. There are paths between them along which a certain restricted spectrum of causal influences and substances may flow. Compare the way in which each sense organ is a partially open system which is "attuned to a special selection of outside processes and at the same time also shielded in other respects."[7]

V. When Does the Human Being Begin to Exist?

We shall assume, for the moment, that everything which satisfies conditions *1.–10.* above, and is of human descent and a product of normal fetal development, is a human being. (We shall find

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[5] R. Ingarden (1984), p. 86.
[6] R. Ingarden, *op. cit.*, p. 90.
[7] R. Ingarden, *op. cit.*, p. 94.

reason to add two further conditions in the sequel, but these are at this stage not pertinent to our argument.)

We take it as unproblematic that there is a chain of events, starting with the movement of the sperm towards the egg and leading on, in normal cases, through birth, and on still further through the acquisition of self-awareness. We also take it as unproblematic that this chain of events in its earliest phases does not yet involve a human being and in its later phases does involve a human being which then preserves its identity through time. This proposition is so strongly supported by our ordinary pre-philosophical intuitions that one would need extraordinary arguments in order to refute it.

If at some earlier time in the course of the development of the foster a human being does not exist, and at some later time a human being does exist, then at some time in the intervening interval a change takes place which is a substantial change. An analogous substantial change—called death—occurs at the end of life.

Compare the case of a larva which turns into a butterfly. The same matter now instantiates one form, now another.[8] Something similar must occur in the course of development of a human being. A given body of living organic matter now instantiates one form (say: that of a cluster of cells), now another (it is a human being: a single, causally isolated, substance). Our strategy will be to establish when in the course of normal human development the conditions for the existence of a single human individual (human being, human organism) are first satisfied. Thus it is sufficient for our purposes that the conditions we present are sufficient conditions for being a human individual when applied to the products of normal human development. We make no claim to have here provided the necessary conditions for being a human individual, and the fact that there are human beings who arise other than through normal course of development is not a problem for our argument.

VI. The Varieties of Substance Formation

The formation of entities can happen in a variety of different ways. Biological species form via budding from existing species. Bacteria form via cell division. The Czech and Slovak Republics were formed through the separation of Czechoslovakia. Budapest was formed via the unification of Buda and Pest. How do human beings form?

Some varieties of substance-formation are *unary* in the sense that they involve a single body of matter which, as a result of its own internal processes, acquires a new form. For example a human being dies and a corpse is formed.

Binary processes of substance-formation and -termination can be classified as follows (with corresponding generalizations for more complex cases):

> i) *Budding*: A part of one individual substance becomes detached and forms a new individual substance in its own right while the original substance goes on existing. We might detach the tail from a cat. Before the loss of the tail, the cat is both one substance and one relatively isolated causal system. Upon the loss of the tail, which is (or terminates in) an abrupt topological change, both the cat and the tail are substances. However, only the cat is a relatively isolated causal system; the tail is just dead matter. Substance formation of a biologically more pertinent sort occurs through budding in those organisms which reproduce by making small dormant cells within themselves and then releasing them into the environment.
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> ii) *Absorption*: A smaller object becomes absorbed into a second, larger object in such a

[8] Aristotle, *Metaphysics*, Z3, 1036a31-b15. Compare Lowe (1998, p. 179).

way that the former undergoes a substantial change and thereby ceases to be a substance. We might attach a new tail to a tailless cat. Before the attachment, cat and tail are separate substances. As a result of the attachment, what had been a separate substance is now a part of the cat.

iii) *Separation*: Two or more entities are joined together as one entity and at some point the relations conjoining the parts of this entity are disrupted in such a way that the previously attached individuals continue as separate new substances. Consider, for example, a pair of Siamese twins who are separated by means of surgery. The connected Siamese twins compose one substance, by our criteria, where the separated Siamese twins are two substances. The Siamese twins, however, constitute two relatively isolated causal systems (and two human beings) both before and after the detachment.

iv) *Fission*: Fission is distinct from separation in that, when an entity (for example a virus) undergoes fission, new parts are formed which then split apart to lead separate existences. An amoeba divides by duplicating its nucleus and then allowing the rest of the cell to split apart – via an abrupt topological change – into two new organisms of roughly equal size. Fission gives rise to new entities and destroys the entity which existed earlier. (Fission is thus distinct from budding which occurs when a very small part of an entity breaks away to form its own separate existence while the original goes on existing as before.

v) *Unification*: Separate individual substances join into a complex which forms one new substance in which the previously detached separate substances continue to exist within the new whole (unification is the dual of separation). Examples of this type of substance formation are found above all in the realm of artefacts (for example when a table is formed by nailing together several blocks of wood).

vi) *Fusion:* Fusion is distinct from unification in that, when entities undergo fusion, they thereby cease to exist (fusion is the dual of fission). Fusion gives rise to a new entity, as for example when two macrophages join together to become one; their respective parts merge to form one (more or less perfect) union.

VII. The Development of the Foster

Our aim is to establish the ontology of the process by which human beings are formed. To this end we will need to consider the biological details of the development of the foster.

The story begins when an egg-cell, developed in the ovaries, is released into the end of the fallopian tube. The egg-cell, swimming free in the fluid-filled tube, is encountered by a sperm, and the latter initiates a process of penetration. (This is what happens in the normal case. In very rare circumstances a sperm cell might attach itself to one of the additional, much tinier cells which are also floating in the fallopian tube. These so-called ‘polar bodies,’ deriving from eggs released at earlier stages in their development, will have a further role to play in the argument below).

Fertilization. The first stage in the process of penetration is the fusion of the membrane of the sperm cell with that of the egg. This results in the passage of the nucleus of the sperm cell into the egg, where the male genetic material that is carried by this nucleus fuses with genetic material from the nucleus of the egg-cell. The two nuclei come into contact in the egg cytoplasm, and shed their nuclear membranes. Each offers up one complete set of 23 chromosomes, and these two sets of chromosomes become entwined around each other as part of a process which transforms the egg-cell into a new joint product, called the zygote, an unusually large cell which

has the same membrane as the egg-cell before fertilization.

Cell Division. Immediately upon formation the zygote begins to undergo a process of genetic replication and cell division. Up to the eight-cell stage there is no qualitative distinction between the cell that is dividing and the cells resulting from the division. The cells are undifferentiated in the sense that any one cell could be removed and still develop into a differentiated fetus. Thus, each has the potential to produce a complete human being (each is, as the jargon has it, 'totipotential').[9] The cells form a mere mass, being kept together spatially by the thin membrane (the *zona pellucida*), which is inherited from the egg-cell before fertilization, but there is no causal interaction between the cells. They are separate bodies, which adhere to each other through their sticky surfaces and which have at this point only the bare capacity for dividing (they neither grow nor communicate). The cells are at this stage still floating free, inside their common membrane, in the fluid-filled fallopian tube, but they have begun to move towards the womb (uterus).

Formation of the Morula. Because of the limited space within the *zona pellucida*, a compaction takes place between the 8- and 16-cell stage (day 3).[10] As a result of this compaction, the inner cells divide faster than the outer cells which surround them. This difference in rate of division is the result of different cell locations. The cells themselves are internally completely similar. At this time tight junctions between the cells are formed; neighboring cells are connected by highly selective permeable membranes through which signal molecules can be transported from one side to the other. The resulting mass of cells is now called a *morula* (Latin for 'mulberry'). The morula is formed as the cells move from the fallopian tube and into the womb.

When there are about 60 cells present (day 4), there occurs a clear visible separation between the so-called 'inner cell mass' and the 'trophectoderm'. The latter is an outer ring of cells which functions thenceforth as the surrounding membrane in place of the *zona pellucida* which disintegrates. In addition, pools of clear fluid which had accumulated between some of the internal cells coalesce to form a common cavity called the *blastocoel* (from the Greek: *blastos*, shoot and New Latin: *coela*, chamber), a body of extracellular fluid in which the inner cell mass thereafter floats. The two groups of cells, taken together with this fluid, are now called the 'blastocyst.' The entire blastocyst itself floats freely in the uterine fluid for about a day and continues to exist disconnected from the mother.

Implantation. Over the next week (days 6-13) there occurs a process called implantation (also 'nidation,' from the Latin *nidus*: a nest, or niche). The blastocyst, on completing its journey along the fallopian tube into the uterine cavity, moves into a position where it is in contact with the uterine wall, to which it adheres via its sticky exterior. Cells on its outer surface then begin to grow rapidly in such a way as to disrupt the surface of the wall. These cells actively burrow into the deeper tissue until they have become completely embedded. The inner cells of the blastocyst are however still not connected to the mother since they float in the liquid contained within the trophoblastic membrane. With the implantation of the blastocyst in the wall of the womb comes the formation from its inner cell mass of what is called the 'embryonic disc.' This consists of two kinds of cell mass: the epiblast, which will eventually give rise to the embryo proper and to parts of the umbilical cord; and the hypoblast which will give rise to extra-embryonic membranes and

[9] Gilbert (1997, pp. 186ff). The success of cloning experiments teaches us that, if massive external intervention in the process of development is allowed, then the property of totipotentiality may be inherited by cells even at very late stages in an organism's existence.

[10] The times indicated here and in the sequel are *times from fertilization.* They are of course approximate only. Variations will arise, for example, according to where in the fallopian tube the egg-cell is fertilized.

tissues.

Gastrulation. When the foster is fully implanted in the wall of the womb (day 13), it is for the first time able to use the nutrients it receives to grow. Until now, only cell division has taken place and thus the foster has not grown in size compared to the egg-cell; rather, its constituent cells have become smaller. Now, however the embryonic disc begins to grow, and at around day 14 there begins the process called 'gastrulation' (from the Latin *gaster*: belly), which gives structure to the embryo in a way that is analogous (perhaps) to the transformation of a body of molten glass into a hobnail vase or to the transformation of a mass of copper threads into a single integrated circuit.[11]

Gastrulation begins with a massive migration of cells to the center of the embryo. Part of the mass of cells folds to create a hollow and then the sides around this hollow close together to form a genuine cavity. Through this topological process of folding and connecting there arise within the embryo three distinct types of site, occupied, respectively, by outward- and inward-facing cells and by cells between these two. This in turn allows a differentiation into types of cells specialized for the production of specific forms of protein. Cells within the ectoderm, or outer tube of the embryo, are predestined to form the skin, hair, nails, the lens of the eye, the nasal cavity, the sinuses, the mouth and nervous tissue. Cells within the endoderm, or inner tube of the embryo, will go on to form the tonsils, larynx, trachea, lungs, and the lining of the alimentary tract. Cells within the mesoderm, or intervening layer, will become the muscle and connective tissue, blood cells, bone marrow, skeleton and reproductive organs.

The foster is now commonly referred to as the embryo proper, a term which is used to describe the developing foster until the ninth week after fertilization, from when it is called the 'fetus.'

Neurulation. Neurulation occurs at or near the end of gastrulation; it transforms the gastrula into a neurula by establishing the beginning of the central nervous system. Here again we have a massive migration of cells which gives rise, via a second process of topological folding and connecting and subsequent cell specialization, to a new sort of structure of the embryo called the neural tube, of which the anterior part becomes the brain and the rest the spinal cord.

A few days after gastrulation there begins to form the fluid-filled amniotic cavity in which the foster will float until the end of its term. This amniotic cavity is within the wall of the uterus, and as it expands it brings about a consequent contraction of the uterine cavity proper. Surprisingly, therefore, the foster is for almost the whole of its development not, strictly speaking *in utero* (it is not inside the womb, or uterine cavity); it is lodged, rather, within a cavity which it has itself created inside the uterine lining and which is henceforth at the heart of a multiple-cavity structure providing a cushion against mechanical injury.

Not all of the cells of the pregastrular foster are predestined to develop into the fetus. Some will form the umbilical cord. Some will form the extraembryonic membranes (the amnion, the chorion and part of the placenta) and other extra-embryonic tissues. The placenta is a flat organ which develops from the outer cell layer of trophoblastic cells in the early embryo which fasten themselves to the wall of the uterus from around day 21. It is the placenta which provides nutrients for the foster during its later development. It is anchored to the mother via a maternal portion formed by part of the functional layer of the uterine membrane. Together with the other fetal membranes (the amnion and the chorion), it disintegrates some moments after birth, when it is delivered through the birth canal.

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[11] Wolpert (1993).

The umbilical cord is an organ of the fetus that penetrates the placenta via two large arteries, which radiate outwards from the point where they break through into the inner surface of the placenta. They then divide into smaller arteries that penetrate ever further into the depths of the placenta through hundreds of branching strands of tissue known as 'villi.' These villi cause a rupturing of the mother's blood vessels in their vicinity and are thereby bathed in maternal blood. The constant circulation of fetal and maternal blood and the very thin tissue separating fetal blood from maternal blood bathing the villi provide a mechanism for interchange of blood constituents between the maternal and fetal bloodstreams. However, it is normally not the case that there is opportunity for the blood of one to gain access to the blood vessels of the other. Rather, nutrients, oxygen, and antibodies diffuse into the fetal blood in the capillaries of the villi, and wastes and carbon dioxide diffuse out of these capillaries into the maternal blood circulation. (Compare the way in which oxygen is transmitted to fish via pipes which feed air into the water of an aquarium.)

Development of the Fetus. At about 40 to 43 days after conception the rudimentary brain (brain stem) at the top of the neural tube begins to form. At the ninth week, the fetus has almost all human physical characteristics (except for the face and genitals) and it begins to show signs of specific male or female development. During the tenth week, the face and the genitals begin to develop. In the twelfth week, when the foster is nine centimeters long, it begins to move its hands and feet. At around the sixteenth week hair also begins to grow and teeth are developed. At around the twentieth week the foster acquires the beginnings of sentience. It can suck and swallow and its body bends and stretches. From then on the foster continues to grow in size until, at day 266 or thereabouts, it is born.

VIII. Alternative Thresholds

Given this account of fetal development, let us return to the question of transtemporal identity. When does the foster first satisfy our ten conditions for being a substance which is also a unified causal system in the sense defined above? The following possibilities can be distinguished:

a. The stage of the single-cell zygote (day 0)
b: The stage of the multi-cell zygote (days 0-3)
c. The stage of the morula (day 3)
d. The stage of the early blastocyst (day 4)
e. Implantation (days 6-13)
f. Gastrulation (days 14-16)
g. Onset of neurulation (from day 16)
h. Formation of the brain stem (days 40-43)
i. End of first trimester (day 98)
j. Viability (around day 130)
k. Sentience (around day 140)
l. Quickening (around day 150)
m. Birth (day 266)
n. The development of self-consciousness (some time after birth)

a. The zygote is a substance: it is a bearer of change; it persists through a time-interval; it is extended in space and it has spatial parts such as the nucleus, the cell-membrane and the filaments inside it; it has its own connected exterior boundary which divides its interior from its

exterior and which connects the parts within its interior and thus distinguishes it from a mere heap or collection. Moreover, the zygote is an independent entity in the sense that it does not require the existence of any specific second entity in order to exist. (Thus it can survive transplantation.) The zygote is, moreover, like every other cell, a relatively isolated causal system. It is shielded by its outer membrane from causal influences deriving from its exterior; the events transpiring within its interior are subject to a division between stable and critical events; and it contains its own rudimentary mechanisms for reestablishing stability in cases of disturbance. But we shall argue that this zygote substance cannot be transtemporally identical to the human being which will exist after birth on the grounds that it is predestined to undergo fission, and this means that it will cease to exist almost immediately after it has been formed. Two zygotes inside the thin membrane are not one but rather two substances. Thus the two-zygote whole is, in our terminology, the result of a substantial change. It follows, as we shall see in detail below, that the unicellular zygote cannot be transtemporally identical to the adult human being.

There is another problem with a view according to which a human being is present already with the unicellular zygote. Consider the so-called 'mosaic chimeras' or twin-within-a-twin individuals.[12] These are single human individuals, most of whose tissues bear the marks of two distinct cell lines which come from two distinct sperm (they may even, in rare cases, come from two distinct fathers). Mosaic chimeras result when one sperm fertilizes the egg and another fertilizes one of the other cells (the already mentioned 'polar bodies') separating at the time of the formation of the egg. The two zygotes may then fuse to form a single individual (which is accordingly a result of a quadruple fusion). If we were to say that zygotes are already human individuals, then we would have to say, in the case where both the egg-cell and a polar body are fertilized, that the two fertilized cell clusters are already two human individuals. In all other respects, however, the final product of their fusion is like every other human being: it is one substance and one relatively isolated causal system, and it has all the characteristics of a normal human individual.

b. At the stage of the multi-cellular zygote-bundle, the zygote is most properly conceived as a sticky assemblage of 8 or 16 entities rather than as a single entity. They are not one but many. Although they are surrounded by a thin permeable membrane, this membrane merely helps to keep the cells together in the spatial sense. There is a flow of nutrients from the outside to the inside of the membrane, but the nutrients are used only for cell division, not for growth, and there is no flow of nutrients or signal molecules from one cell within the bundle to another. So the cell bundle has no stability-restoring mechanism of its own of the sort which is required in order for the whole entity to be a single causal system. The multi-cellular zygote cannot even lay claim to the type of unity that is possessed by colonial organisms, such as certain forms of yeast, whose parts are connected via an exchange of fluids or signal molecules. The cells in the multi-cellular zygote simply just divide, and they do this independently of each other.

Perhaps, though, we can hold on to the view that the multi-cell zygote is already a human individual by arguing that some one cell within the bundle is privileged by the fact that it inherits from the original single cell the property of serving as the bearer of identity for the human being that is in process of development. The problem with this view is that it contradicts totipotentiality—the feature in virtue of which each of the cells within the multi-cell zygote has the full potential to develop into a human being.

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[12] Gaddis and Gaddis (1972, pp. 30ff), Mayr et al. (1979), and Gilbert *op. cit.*, pp. 186 ff.

To see the problem here, we must turn to the question of how differentiation works. Differentiation is the creation, from a mere mass of homogeneous cells, of clusters of functionally and structurally different types of connected tissue at different sites. In the case before us, all the cells maintain forever the same genetic composition (that of the original fertilized egg-cell). However, the very genes involved contain the programming for differentiation (and each of the cells contains all this programming). The programming goes into effect in different cells in different ways, not because of any intrinsic features of the cells themselves, but rather as a result of the specific environments surrounding them and thus of the macroscopic structures which they together go to form. This surrounding context determines that some of the genes within each given cell become repressed, so that only some types of protein are made. That it is the environment surrounding a given cell which determines what kind of proteins will be formed (or 'expressed') by the cell can be seen from the fact that, if cells of a given type are moved artificially to a different environment where they are surrounded by cells of a different type, then they will begin to express the same proteins as the cells which surround them. Since, at the stage of the multi-celled zygote, no differentiation has taken place, it follows that there can be no cell or bundle of cells within the cluster which is privileged in virtue of some intrinsic feature which it might possess.

c. At the formation of the morula, too, differentiation has not yet taken place, and so the just-mentioned argument can be applied in this case also (as also in cases d. and e., below). Each of the cells of the morula still has the potential to become a human being. At this stage, junctions between the cells of the zygote are formed which allow intercellular communication by means of small signal-molecules. But the morula still fails to meet condition *10.* for being a causally isolated system. That is, it does not possess mechanisms of its own to restore stability in cases of external disturbance. At best it must rely on the separate rudimentary stability-restoring mechanisms of its separate constituent cells.

d. At the stage of the early blastocyst, the cells have separated into the inner cell mass and the surrounding trophoblast. The inner cell mass constitutes a single substance, rather than many substances, insofar as its cells together form a connected whole with a common physical boundary; but it still lacks its own internal mechanisms in virtue of which its several parts would in case of disturbance work together as a whole to restore stability. The inner cell mass will differentiate into two further tissues, only one of which will eventually become the embryo. The other will turn into extraembryonic membranes and tissue. This is not in and of itself important for determining whether or not the inner cell mass is transtemporally identical to the later human being, for one may argue that the mentioned tissues are merely temporary parts of the embryo in much the same sense as baby teeth are temporary parts of the child. What is important, however, is that, following our account of differentiation above, it is not yet determined which parts of the inner cell mass are predestined to become embryonic cells. In fact, each has the same potency in the sense that each can, through transplantation, be brought into a position where it will develop into an embryo in its own right.[13] Thus the stage of the early blastocyst at day 4 does not yet seem to be a good candidate stage for the formation of the human being.

e. When the process of implantation comes to an end, the embryo can begin to use the nutrients it receives from the mother for growth, and it can begin to grow as an individual and to

[13] Gilbert, *op cit*, p. 186.

differentiate into tissues of different sorts which are recognizable precursors of neonatal tissues. However, as for the early blastocyst, so also here, it seems that the foster still lacks its own integrated mechanism for restoring stability, and so it fails to be a relatively isolated causal system in the sense at issue here. An identification of the foster with the later human being faces now however the additional problem that the foster, through its intensified activity and growth, has entered into a condition of being dependent on the mother for nutrients and oxygen. Does this imply that the foster is henceforth such as to fall short of being a substance because it does not satisfy condition *6.*? Certainly, if it is extracted from the mother it will almost certainly die through lack of an appropriate protective environment. But this applies also, for example, to a mature fish in relation to a surrounding environment of water or to an Arctic explorer in relation to her winter ice station. It is known from the animal kingdom that premature offspring can often survive in external environments. A kangaroo foster, for example, is born alive at a very immature stage when it is only about one inch long and weighs a single gram. After birth it uses its forelimbs to crawl up the mother's body and enter the pouch, which is a pocket on the mother which opens forward and contains teats. As the baby kangaroo grows, it gradually spends more and more time outside the pouch, which it leaves for good at the age of seven to ten months. The amniotic cavity in which the human foster develops upon implantation is in the ontologically relevant sense like a kangaroo pouch, though instead of being open it is a closed cavity.

To see our way clearly here we must distinguish specific dependence—which is what is at issue in condition *6.*—from generic dependence, the relationship which holds, for example, between a human being and molecules of oxygen. As the kangaroo foster is not specifically dependent on its mother, but only generically dependent on an appropriate environment (with teats and so forth), so the human foster is not specifically dependent on its mother, but only on a similarly appropriate environment, which might be supplied by means of an incubator. Certainly, the foster is not dependent on the mother in the sense of specific dependence that is involved, for example, in the relation between a smile and a human face, or between an individual instance of color and some extended surface—a sense of dependence which excludes migration from one host or carrier to another.

f. It is with gastrulation (around day 16) that the foster ceases to be a cluster of homogenous cells and is transformed into a single heterogeneous entity—a whole multicellular individual living being which has a body axis and bilateral It is with gastrulation that the embryo's cranial axis and its dorsal and ventral surfaces come into existence, and it is from this point that the boundaries of a discrete, coherent entity have been formed. The gastrular foster also meets condition *9.* in virtue of the fact that it is protected against outside disturbance by its own surrounding jacket of cells. That is to say, there is at this stage formed a bona fide spatial boundary which delineates the embryo spatially from the extraembryonic tissue.[14] Gastrulation brings a new type of integration of the foster, which is manifested in the fact that twinning is from this point no longer possible.[15] If fission occurs just prior to gastrulation, this will in almost all cases give rise to progressively more serious malformations (Siamese twins). Such deformities, as metallurgists who deal with stress in metals know, are characteristic of abrupt topological change. They give us strong reason to believe that an account of the beginning of

[14] This is in agreement with Ford (1988).

[15] Indeed not only fission but also fusion is possible in the pre-gastrular phase. Thus it has been shown that multicell zygotes from distinct mice can be artificially integrated to form a common compacted morula. Similar experiments fail at later stages. (Gilbert 1997, p. 187.)

human existence as lying within the gastrular phase is more than a mere definitional or conceptual stipulation.

For all of these reasons we shall argue that, while human life is present at earlier stages, it is gastrulation which constitutes the threshold event for the beginning to exist of the human individual.

g. Neurulation is a gradual process which for present purposes can be seen as being extended seamlessly to include all the subsequent processes of brain development, including those which occur after birth. It is not least because neurulation is a gradual process, and because the development of the brain is so intimately connected to the development of reason and consciousness, that many have held that the moral status of a human individual changes gradually from the time when it begins to exist to some time after birth. But the incremental character of the formation of nervous tissue implies also that it will be difficult to isolate a singularity in the process of neurulation which might serve as the threshold event of substance formation. One such singularity is the point at which neurulation begins. This, however, coincides with the end of gastrulation, which is on independent grounds our preferred threshold for the beginning of human existence.

h. Another such singularity occurs at 40-43 days and is the formation of the rudimentary brain or brain stem. The proponent of alternative h. as threshold is asking us to accept that a change within a certain part of the matter of an object would constitute a substantial change in the object as a whole. We do not rule out the possibility that a thesis along these lines might be true—something similar might apply, after all, at the end of life, in the case of brain failure.[16] Where it is reasonable, however, to conceive of death as an abrupt change—so that the same piece of matter instantiates now one form, now another—it seems difficult to conceive of any similarly abrupt threshold associated with what is, after all, the mere intensification in one site of the process of neurulation that has been taking place throughout the whole body since day 16. Perhaps a change of this sort has some moral significance and thus it might prove important for settling ethical issues, but it does not mark the beginning of a human individual.

i. The threshold used in many countries as the standard criterion for permissibility of abortions is the end of the first trimester, the stage when the foster is commonly held to have acquired the visible traits of a prototypical human being. Because the process of coming to resemble a human being is a gradual one, however, this threshold, too, falls out of account as marking a substantial change.

j. It has often been suggested that the human individual begins to exist at the point when the foster becomes *viable*; that is, when it can live outside its mother's womb. The argument is that prior to this time the foster cannot survive independently of its mother; hence it is analogous to an organ of the mother, which can only exist and exercise its proper function within the locus of its proper encompassing environment. The problem with this view is that the transition to viability does not in itself connote a transformation of one entity into another. Rather, it represents a mere Cambridge change of the sort which may be expressed by a proposition such

[16] See Hershenov (2002), who points to the asymmetry in Olson (1997, 1997a), who uses brainstem destruction as criterion for determining the time of death of a human being while giving the formation of the primitive streak as criterion for origin.

as 'Mary just ceased to be the tallest player in the team.' This is because, while acquiring stronger muscles is a real (though not a substantial) change, the satisfaction of the viability criterion is not dependent on such physical changes in the foster; it may be satisfied through advances in technology in the wider surrounding environment.

k. Sentience: There are some[17] who would identify the acquisition of the capacity for sentience as marking the point when the human being begins to exist (based upon an identification of human being with: human sentient organism). Such a dispositional property requires in every case some underlying basis which is not itself merely dispositional. The corresponding physical change in this case might be an increase in complexity of nerve-connections in the brain. This means, however, that the proponents of alternative k. are asking us to accept that a change within a certain part of the matter of an object would constitute a substantial change in the object as a whole. The arguments against alternative h. thus apply here also.

l. Quickening signifies the time when the foster can first be felt as moving, a time which was historically often held to mark the point when abortion becomes impermissible. Again, however, quickening does not mark a change in the foster. Rather, it marks a change in the (phenomenological) relation between foster and mother. The underlying change in the foster is once again a gradual change—a change in complexity and intensity of fetal movements—and it thus falls out of account as marking a substantial change of the sort which is at issue here.

m. Many have held that it is the event of birth which marks the initiation of the human being. Consider, for example, the Talmudic doctrine according to which the foster is a limb of the mother, so that only once its head has emerged from the mother's body does it begin to exist as a substance in its own right. We shall argue below, however, that birth is the mere passage of an entity from one environment to another (it is analogous to an astronaut leaving her spaceship). Thus it is a process of a sort that does not affect any substantial change in the entities involved. If the human being exists at birth, then it exists also in the minutes prior to birth, and then our question as to when the human individual begins to exist arises once again.

But might we not take an alternative view, according to which the concept *human being* is not a substantial concept at all, but rather a relational concept, so that to be a human being is to be, inter alia, in a certain sort of environment? (Compare the way in which the concept of a pawn is tied to the environment of a chess game.)[18] To see what is wrong with an approach along these lines we need only consider a thought experiment in which a fetus remains in a specially tended and adapted womb/incubator perhaps for many years beyond its term, growing and acquiring many of the features normally considered as characteristic of a mature human being, including features of reason and consciousness. The organism in question would not be a human being, on the relational understanding.

n. The final alternative is that it is the acquisition after birth of some extra feature which marks the beginning of the human individual. This extra feature is what makes the foster a human being. One obvious candidate (at least since Locke) is consciousness, and in particular self-

[17] For example Lockwood (1985).

[18] Compare also the so-called ecological approach to species, according to which an organism belongs to a given species, not in virtue of its intrinsic features but rather in virtue of relations which obtain between the organism and its environment (i.e. the niche or niches which it occupies). See Mayr (1996).

consciousness.[19] This alternative, too, falls prey to the arguments advanced above in connection with alternatives h. and k. Above all, it seems difficult to conceive of any abrupt threshold associated with the transition to consciousness that would constitute a substantial change in the organism considered as a whole. The principal argument against alternative n., however, as also against alternatives h. through m., turns on the fact that an individual has already been formed at a prior stage (the stage of gastrulation/neurulation), and this individual satisfies all our conditions for being a human being. This leaves no ontological room for a second initiation of human existence.[20] The same human being cannot begin to exist on two separate occasions.

IX. Twinning

Even if it can be definitively established that there exists a human being at the stage of gastrulation, there still remains the issue of whether this individual exists already at some prior stage.

Let us return, once again, to the unicellular zygote. This, we said, satisfies our ten conditions, but it fails as a candidate first-stage human being because it is predestined to undergo an almost immediate process of division. The zygote is, we might say, actually one but potentially many. All organic entities lose parts over time (as you lose hair and skin). Some organic entities, for example amoebae, flatworms, molds and yeasts are such that they can in addition divide naturally (which is to say: without external intervention) into two or more entities which are similar to themselves.[21] Human beings and other higher organisms, in contrast, are unitary individuals in the strong sense that they cannot be subject to a division of this sort (or if they can, then only through massive external intervention). They satisfy, in sum, a condition of the following sort.

> *11*. An entity is *non-divisible* if and only if the parts of the entity are integrated together in such a way that it is not possible that the entity should in and of itself divide in such a way that it goes out of existence and is replaced by two or more entities which themselves satisfy conditions *1.-10.* above.

The phrase ‘in and of itself’, here, is designed to exclude the cases where human beings are subject to division through external intervention (for example via something like a three-dimensional photocopying process) of the sort which at present is confined to the realm of science fiction.

Plants and fungi can divide to form new individuals because their cells are relatively undifferentiated. In the case of higher organisms, however, the foster has by the end of gastrulation taken on the character of a heterogeneous individual made up of cells possessing different regional properties determined by their different sites within the whole organism. This division of the cytoplasm begins after implantation, when the properties of specific cells depend on their positions within the blastula determined by the outcomes of earlier cleavages. The different regional properties then established determine the different trajectories of the corresponding cells in that massive migration of cytoplasm and resultant folding and connecting which is gastrulation itself. When this reorganization has been effected, any natural division of

[19] Compare Brody (1975) and Tooley (1983, p. 167). Tooley argues that the personhood of the relevant entity begins when it has the capacity to care about its own continued existence.
[20] Compare Olson (1997).
[21] See J. Wilson, *op. cit.*

the whole foster of a sort which will produce successor fosters is impossible. This is because the parts resulting from any such division would not have the programming for the sort of folding and reconnecting that would be necessary for renewed development.

We know that at every pre-gastrular stage the foster is able to undergo division in such a way as to give rise to two or more distinct human individuals. Condition *11*. thus rules out alternatives a.-e. It implies that, even in those cases where twinning does not occur, the foster cannot be transtemporally identical with the human individual which exists after birth at any stage where twinning is still *possible*.

As the American Civil war teaches us, however, there are cases where identity is inherited even though an entity is susceptible to twinning. Might one therefore conclude, by parity of reasoning, that identity can be similarly inherited across the gastrular divide? To gauge the merits of such a claim we need to focus carefully on the three alternative scenarios under which twinning might occur, corresponding to the three varieties of substance formation by division—budding, separation and fission—distinguished above.

On the first scenario the foster would, in some pre-gastrular phase, be such that a process of forming new human individuals can still occur via *budding*. Someone might hold that the human individual could already exist at a stage where twinning is still possible because twinning, on this account, is in fact a form of cloning. Again, similar phenomena are known from the vegetable kingdom, where a cutting from one plant may be planted in the soil to result in a new plant without the original plant ceasing to exist as a separate individual. Unfortunately, however, human development is nothing like that of plants. When a cutting is taken from a fully developed plant we do not have one cell or mass of cells which divides into two. Rather, the situation is analogous to one in which one would grow a new human individual from a nail or a lump of hair.

On the second scenario the foster is, in some pre-gastrular phase, such that a process of forming new human individuals can still occur via *separation*. This would mean (by the definition of separation) that the foster is already not one but two entities, both of which would survive, should twinning occur, to form two independent fosters. Two accounts must now be considered of the case where twinning does not in fact occur. On the first account one of the two parts of the foster is transtemporally identical to the human being that will exist after birth. On the second account identity applies rather to the foster as a whole, as it exists in a phase when twinning via separation is still possible.

The first of these alternatives can be rejected on *a priori* grounds. First, it implies a peculiar process under which—as twinning fails to occur—one human being would absorb into itself another entity that is of exactly analogous form and structure. But more importantly, it leaves open the question as to what might make it true that one but not the other half of the total foster as it exists prior to gastrulation should be the human being which exists after birth. Thus it provides nothing to which we could point as the human being at stages when twinning of the given sort is still possible.

The second alternative account is not so easily excluded. Consider the United States in the period immediately prior to the Civil War, a time when, as we know, a separation of a single whole entity into two parts was still possible. The United States was then actually one but potentially two. But separation did not in fact occur. Could we not then say, by parity of reasoning, that, at the stage when twinning via separation is still possible but does not in fact occur, the whole foster is transtemporally identical to the human being which exists after birth? The difference here is that the United States in 1860 already existed as one entity of the same type as the United States as it existed from 1866. We could assert that there is parity between the

Civil War case and the case which here concerns us only if we could assert that the pre-gastrular foster, too, already existed as one entity of the same type as the human being as it exists after birth—but that is precisely what is here open to dispute.

On the third scenario, finally, we are to consider a foster in the pre-gastrular phase when twinning might still occur via *fission*. Here, it might be argued, we have in the foster a structure analogous to that of an amoeba, whose interior bonds are insufficiently strong to prevent division, but which are yet sufficiently strong to constitute a unity. Now, as in the case of the United States in 1860, so also here, we have no hesitation in asserting that the identity of the amoeba persists across an interval during which it is susceptible to fission but does not, in fact, divide. To conclude from this analogy that the human being might exist already in the pre-gastrular phase would, however, be once again to beg the question, for it would amount to the postulation of a unitary foster already in the period when twinning can still occur. The analogy does, however, cast doubt on attempts to use the fact that twinning is still possible at a given stage as the basis of an a priori argument against the thesis that the human being might already exist at that stage.[22]

The upshot is that we can indeed still allow the possibility that the human being exists already before gastrulation—but then only at the price of allowing that human beings, like amoebae, flatworms, and republics, can contain within themselves the potentiality for division. Or alternatively, we can continue to insist—in the spirit of our condition *11*.—that the existence of human beings (and of other higher organisms) presupposes that type of unity (conferred by gastrulation) which excludes this potentiality. Both options imply on *a priori* grounds that the human being begins to exist *no later than sixteen days after fertilization*. Empirical consideration of the biology of pre- and post-gastrular development then allows us to identify the relevant substantial change as occurring at the very end of the sixteen day period.

X. The Concept of Niche

But we are not yet done. For consider John's heart. This is a substance, and it is a relatively isolated causal system; it is non-divisible; and it is a product of human reproduction; yet it is not itself a human being because it is not a *maximal* entity satisfying these conditions: it belongs as proper part to John's organism as a whole. We need, then, to add one further condition to our list, to the effect that a substance, to be a human being, must be maximal in the relevant sense. This issue is by no means trivial. Considerations of maximality will however bring the additional advantage that it will throw light on the precise nature of the relationship between foster and mother.

The problem we face in formulating a condition on maximality turns on the fact that John himself is not a maximal causally isolated substance in all the phases of his existence. Suppose that John is inside a spaceship and is working the ship's controls. The mereological sum of John and the spaceship is then a substance, by our criteria above. It is also, to a degree, a relatively isolated causal system. But there is a difference between John in his relation to the spaceship, on the one hand, and John's various cells and organs in their relation to John's whole body, on the other. For John is not a *part* of the spaceship. Thus he is not in the spaceship in the way in which, for example, a nucleus is in the cell or the heart or brain is in the body. Rather, John is in the spaceship as a bird is in its nest or as a bear is in its cave. More generally, John is in his spaceship as an organism is in its niche (which means, *inter alia*, that he can leave the ship and then return, he can be replaced by another human being at the ship's controls, and so on).

[22] See especially Ford, *op. cit.*, pp. 111ff., 172f.

Intuitively, a niche is a part of reality into which an object fits, and into and out of which the object can move. A niche and its tenant do not overlap (they have no parts in common). Rather the niche *surrounds* its tenant.[23] Moreover, the niche-tenant relation must involve some sort of cavity—of air, water, or some other medium—in which the tenant is contained. The tenant is then separated via this medium from any surrounding physical retainer. Niche and tenant thus share no boundaries in the way in which, for example, a cat(-torso) shares a boundary with its tail, and the surrounding relation between a niche and its tenant is accordingly to be distinguished from a relationship of perfectly tight connection of the sort we find, for example, in the case of *David* trapped within the interior of the block of stone before Michelangelo gets to work. Rather there is on all sides a degree of free play between the niche-retainer and the tenant housed inside it.

Let us suppose that John is involved in an accident which destroys the skin over the entire surface of his body. On one scenario, the doctors graft a new synthetic skin onto his body that is made of some organic material that is biologically mimicking John's own cells. On another scenario they create a space suit-like cover for John, which he will henceforth wear. In the former case, we say that the synthetic skin is a *part* of John (the doctors have created for John a new, synthetic organ). In the latter case, we say that the spacesuit creates a *niche* for John, into which John fits, and which is then such that John and his niche have no parts in common. Note that the issue here does not turn on what the skin, or suit, is made of. We can imagine, for example, some future spacesuit-like container-niche for John that is constructed out of human protein teased into weavable plastic form.

We can now lay down our needed supplementary criterion as follows. Intuitively, we want it to be the case that a maximal entity in the sense here at issue is an entity which, if it belongs as part to a larger substantial whole, then only because it stands, within this larger whole, in a tenant-niche relationship. In sum:

> *12*. An entity *x* is *maximal* if and only if every entity *y* which (1) satisfies conditions *1.–11.* and (2) has *x* as proper part, has some other proper part which is a niche for *x*.

Thus if *x* is John, who is alone inside a spaceship, then one relevant value of *y* is: John plus the spaceship (the two mereologically summed together), and the relevant niche is then just the spaceship itself. John is not a part of this niche, but rather (trivially) a part of the mereological sum of the niche (including the medium) together with himself.

An interesting illustration of the workings of this condition is provided by the case of cryogenically frozen human beings. We are to imagine a living human being whose metabolism is suppressed by freezing and who is preserved in the frozen state by means of some surrounding refrigerator-like mechanism. Here, the organism's own mechanisms for sustaining and restoring bodily stability are put out of action and the tenant of the cryogenic niche borrows these mechanisms from its new artificial surroundings. Yet the organism still has these mechanisms (even if in a dormant state), and thus our twelve conditions are still satisfied.

Our remarks on cryogenically frozen human beings can throw further light also on the question whether human beings in general might be formed at some very early stage in their development (e.g. at the stage of the single zygote) though in such a way that the capacities which make them relatively isolated causal systems would exist only in a dormant form. Viruses

[23] The notion of surrounding niche that is here at work can be more precisely specified by using the tools of mereology, topology and the theory of spatial location. See Smith and Varzi (1999), (2002).

and other marginal kinds of life may display for long periods a complete lack of metabolism, but the virus still preserves its potential to engage in an active, self-replicating phase when it is coupled to the metabolism of more complicated host organisms. The same goes for simple animals (for example some shrimp species) which are able to stay completely metabolism-free during long, cold seasons, but yet retain the capacity to display metabolism in other phases of their existence. What counts against drawing conclusions from such cases for the early foster, however, is once again the phenomenon of fission.

XI. Is the Foster Connected to the Mother?

Any entity which is the product of normal human reproduction and which satisfies our twelve conditions will be a human being. We can thus lend further weight to our conclusions above if we can establish that these conditions are first satisfied by a developing foster in the normal course of fetal development at sixteen days after fertilization. It is from this point that the foster constitutes a single substance with its own external physical boundary, and it is from this point that it begins to develop the mechanisms it needs for restoring its own stability. Most importantly, the foster is from this point non-divisible. It remains to show that the post-gastrular foster satisfies also the maximality condition (*12.*). We need to establish, in other words, that every entity containing the foster as proper part which satisfies conditions *1.*-*11.* has, from this time, some other part which is a niche for the foster. Since the only candidate for such an entity is (or involves) the mother, we need to establish the nature of the relation between the foster and the mother: is it that of tenant to niche, or that of part to whole, or is it some other sort of relation?

It will help to distinguish here between 'fiat' and 'bona fide' boundaries.[24] Fiat boundaries are boundaries which correspond to no underlying physical discontinuities. Examples are found above all in the realm of arbitrarily demarcated geospatial entities such as postal districts, census tracts, or air traffic corridors. Bona fide boundaries, on the other hand, are physical discontinuities in the usual sense of this term: for example the edge of this table, or the surface of that painting, or the outer boundary of your heart or lungs. Recall our conditions *4.* and *7.*, according to which each substance must possess its own complete, connected boundary which divides its interior from its exterior and which is established via a covering or membrane which extends continuously across all or almost all of its surface. This means that the boundary of a substance is a bona fide boundary for all or almost all of its extent and that where the boundary falls short of bona fide status this is because fiat boundaries are formed in virtue of apertures in the shield or membrane, for example in the region of the mouth or nostrils. (To say that fiat boundaries are formed is to say simply that the line between interior and exterior in the region of such apertures corresponds to no physical discontinuity. You can create a fiat boundary of this sort, as a part of the total boundary of your office, by opening your office door.) Siamese twins, which have a part of their surface in common, are also separated by a fiat boundary along the plane where they meet.

These remarks are important since, as will now be clear, substantial changes are closely connected to topological changes—to changes in boundaries and in connectedness—and such changes can be properly understood only if careful attention is paid to the fiat/bona fide opposition. Two entities have the same topology, roughly speaking, if one can stretch, bend, shrink or expand the one entity, without tearing or joining, in such a way as to lend it a form that is identical to that of the second entity. Two entities will then have the same topology if and only

[24] Smith and Varzi (2000).

if they have, across their surface and interior, analogous distributions of fiat and bona fide boundaries. A newly born child has in most cases (some Siamese twins provide exceptions) the same topology when it is born as it does after it has turned six. A tail that is attached in the normal way to the body of a cat does not have the same topology as it would have if it were detached from the cat: this is because before detachment its boundary includes a fiat as well as a bona fide portion.

Fiat boundaries are involved whenever an organism undergoes a process of division. As an amoeba splits, its middle part becomes progressively thinner so that we can talk in terms of two halves of the amoeba with a fiat boundary running between them within the interior of the whole. As the middle part shrinks, this fiat boundary separating the two halves goes out of existence, incrementally, until the point is reached when it disappears entirely. A long, continuous process suddenly results in an abrupt topological change. The right and left portions split, and we have two amoebae, each with its own complete bona fide boundary.

Fiat boundaries are involved whenever one entity is strictly connected to another. The tenant-niche structure, as we saw, excludes the possibility that tenant and niche may be strictly connected to each other. Thus if the foster is connected to the mother—if, in other words, the boundary between the foster and the mother is a matter of fiat and not of bona fide boundaries—then the foster cannot stand to the mother in the niche-tenant relation, and thus it cannot satisfy condition *12*.

But as we have seen, there is at no stage after ovulation a strict topological connection between the foster and its mother. Such a connection is not even established in the form of a canal or tube through which blood or nutrients might flow. The communication taking place between the foster and the mother involves many separate processes of cell diffusion, but these processes occur always via some intervening liquid-filled cavity; they never involve the presence of that sort of common membrane which would be required for strict topological connection. It is for this reason that birth is most properly conceived as the passage of an entity from one niche or environment to another.

XII. Is the Foster a Part of the Mother?

Before we can finally establish the relation between the foster and the mother, however, we still need to consider the status of the amniotic cavity (the cavity created by the foster within the interior of the uterine lining). Is this a part of the mother? Or is it a genuine cavity, disjoint from the mother, even though lying within her interior?

Suppose a visitor is inside your house. Or suppose a tub of yogurt is inside your refrigerator. The yogurt is in the interior of the refrigerator; but it is not a part of the refrigerator. Indeed it and the refrigerator share no parts in common. Rather, it is lodged within a cavity within the interior of the refrigerator, and it relates to the refrigerator as a tenant to its niche. The refrigerator is one substance, the tub of yogurt is a second substance, and the former surrounds the latter. Topologists distinguish in this connection between an object and its convex closure (the latter is, intuitively, the result of filling all the holes within the former). If we say: the tub of yogurt is inside the refrigerator, then we mean that its spatial location is a part of the spatial location of the convex closure of the refrigerator.[25]

Consider the digestive tract. Is this a tunnel through your body, and thus a *hole*, analogous to the interior cavity of the refrigerator? Or is it rather an organ within your body and thus a *part*, analogous to the door or thermostat of the refrigerator? Certainly the throat, esophagus, stomach,

[25] See Casati and Varzi (1999, ch. 8).

and colon are parts of the body as systems of cells, and these systems of cells are counted as such by anatomists. The canal which they together form, however, is a genuine cavity. Its function is, like that of the mouth, to serve as a protected antechamber which is able to withhold ingested substances from the body in order to make it possible for the initial digestive processes to proceed. It is accordingly counted by immunologists as discrete from the body and as belonging rather to its environment.

And so also, we now wish to claim, in the case of the amniotic cavity in which the foster is lodged. This, too, is to be identified not as an organ or limb of the mother, but rather, precisely, as a cavity within her interior. Thus the foster, too, because it is included in this cavity, is not a part of the mother either. Hence there is nothing standing in the way of our asserting that the foster occupies a niche within the interior of the mother in a way that is analogous to a palm kernel that is lodged within your digestive tract, or to the kangaroo joey that is lodged inside its mother's pouch. The maximality condition (*12.*) is therefore satisfied. The foster is in this respect analogous also to a parasite which occupies a host organism. Fosters, like parasites, are both substances and relatively isolated causal systems; they are not parts of their host organisms but are related to them, rather, as a tenant to its niche. Fosters are, on the other hand, unlike tumors, since the latter are, by our criteria, proper parts of the affected host organism.

XIII. Stages in the Formation of the Human Substance

We can now give a more thorough account, in ontological terms, of the multi-stage process whose result is the formation of a human individual. The single-cell zygote is formed via the unification of two separate substances: the egg-cell and the sperm-nucleus. The functional parts of the zygote then undergo a duplication within the cell, and the topological connections between these parts are disrupted in such a way that they come to constitute, via separation, new substances in their own right. These separate substances are reunified into one at the stage of the early blastocyst. A part of this one individual substance is then detached from the remainder and forms a new individual substance (namely the inner cell mass, or what will become the embryo) in a budding process which involves the simultaneous creation of an interior cavity in which what buds off then resides.

At gastrulation, the still weakly unified embryo undergoes a process of integration. This occurs through a gradual formation of ties between the cells of the aggregate, through the gradual development of a bona fide physical boundary marking out the individual in space, and through a gradual process in virtue of which groups of cells become successively determined to become tissues of specific sorts in reflection of their specific relative locations within the whole.

The above does not, however, imply that the human being is formed by increments across a temporal interval (an outcome which would carry an implication to the effect that different human beings might be human beings to different degrees). This is because the mentioned unifying process is almost instantaneous (compare the unifying process which occurs when two drops of water become one). It thus constitutes a bona fide temporal boundary, in much the same way in which a bona fide spatial boundary may be established between two parcels of land by a river or wall. A collection of continuous processes within the foster gives rise in this fashion to a boundary in time. The unification processes which take place at gastrulation together have the consequence that they bring about an integration of the foster that is strong enough to rule out the possibility of twinning. They bring about, in other words, a transformation from divisibility into non-divisibility. (A parallel phenomenon at the end of life brings about an analogous transformation called death.)

But surely, it might be argued, all natural change is continuous.[26] How, then, can it be possible to identify a boundary in time at which a human being begins to exist? Consider what happens when we move from the issue of temporal discontinuity to its analogue in the spatial realm. Human beings and other organisms, clearly, have spatial boundaries formed by their skin or hide. The latter are genuine discontinuities even in the face of the continuity of matter in the physical world. And so also, we must now conclude: the lives of human beings have temporal boundaries—their beginnings and endings—which are genuine discontinuities even in the face of the continuity of the physical, chemical and biological processes in which they are involved.[27]

References

Birnbacher, D. (1995). Gibt es rationale Argumente für ein Abtreibungsverbot? *Revue internationale de Philosophie*, 3, 357-373.

Brody, B. (1975). *Abortion and the Sanctity of Human Life: A Philosophical View*. Cambridge, MA: MIT Press.

Casati, R & Varzi, A. C. (1999). *Parts and Places. The Structures of Spatial Representation*. Cambridge, MA: MIT Press.

Ford, N. M. (1988). *When Did I Begin? Conception of the Human Individual in History, Philosophy and Science*. Cambridge/New York: Cambridge University Press.

Gaddis, V. & Gaddis, M. (1972). *The Curious World of Twins*. New York: Hawthorn Books.

Gilbert, S. F. (1997). *Developmental Biology*, 5th ed. Sunderland, Mass.: Sinauer Associates.

Hershenov, D. (2002). Olson's Embryo Problem. *Australasian Journal of Philosophy*, 80 (4), 502–510.

Ingarden, R. (1984). *Man and Value*. Munich: Philosophia.

Lockwood, M. (1995). When Does Life Begin?. In M. Lockwood (Ed.), *Moral Dilemmas in Modern Medicine*. New York: Oxford University Press.

Lowe, E. J. (1998). *The Possibility of Metaphysics: Substance, Identity, and Time*. Oxford: Clarendon Press.

Mayr W. R. et al. (1979). Human Chimaera Detectable only by Investigation of Her Progeny. *Nature*, 277, 210-211,

Mayr, E. (1996). What is a Species, and What is Not. *Philosophy of Science*, 63, 262-77.

Novak, M. (1963/64). A Key to Aristotle's 'Substance'. *Philosophy and Phenomenological Research*, 24, 1–19.

Olson, E. T. (1997). Was I Ever a Fetus? *Philosophy and Phenomenological Research*, 57, 95-110.

Olson, E. T. (1997a). *The Human Animal*, Oxford: Oxford University Press.

Smith, B. (1997). On Substances, Accidents and Universals: In Defense of a Constituent Ontology. *Philosophical Papers*, 26 , 105-127.

Smith, B. & Varzi, A. C. (1999). The Niche. *Nous*, 33, 214-238

Smith, B. & Varzi, A. C. (2000). Fiat and Bona Fide Boundaries. *Philosophy and Phenomenological Research*, 60, 401–420.

Smith, B. & Varzi, A. C. (2002). Surrounding Space. On the Ontology of Organism-

[26] Birnbacher (1995).

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Environment Relations. *Theory in Biosciences*, forthcoming.
Tooley, M. (1983). *Abortion and Infanticide*. Oxford: Clarendon Press.
Wilson, J. (1999). *Biological Individuality: The Identity and Persistence of Living Entities*. Cambridge: Cambridge University Press.
Wolpert, L. (1993). Gastrulation and the Evolution of Development. In W. D. Stein and F. J. Varela (Eds.), *Thinking About Biology* (pp. 169-182). New York: Addison-Wesley Publishing Company, 1993.