Embryontology[1]

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As gerontology deals with the end of life so embryontology deals with the beginning of life, with the question: 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.

Foster: The term 'foster' refers in neutral fashion to the human zygote, embryo, or fetus at different stages of development. It should be understood, by analogy with terms like 'president' or 'customer', as a phase sortal or definite functional description meaning: organic entity possessing a full set of chromosomes and inhabiting the fallopian tube, uterus or uterine lining.

Need for Ontology: It is sufficient to use our unaided common sense in order to establish that, for example, mature adults are human beings. But our common-sense concepts are found wanting when it comes to answering the more difficult question concerning when the foster becomes a human being. 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.

Three-Dimensionalism: 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. I am the same (numerical identical) human being as I was one year or one minute ago.

Conditions on Substance:
Human beings and other higher organisms then satisfy the following six conditions, which are the marks of the philosopher's concept of an individual physical thing or substance:[2]

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.)
2. Each substance is an entity which persists through time. It remains numerically one and the same 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.)
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.)
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 being 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 specific 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).

A Siamese twin will fail to satisfy condition *4.* and *6.*

What happens when an amoeba splits into two is that there is a rapid thinning out of matter in the immediate area of separation by until, suddenly, at the end of this process, we have a separation: from one substance there is two.

Organisms as Causal Systems

The six criteria listed above 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 closed box together with a set of wooden bricks which have been placed inside it. And they are satisfied by a whole consisting of various

1. This essay was inspired by D. Birnbacher, "Gibt es rationale Argumente für ein Abtreibungsverbot?," *Revue internationale de Philosophie* 3 (1995), 357-373.
2. Compare M. Novak , "A Key to Aristotle's 'Substance'," *Philosophy and Phenomenological Research*, 24, 1963/64, 1-19, and B. Smith, "On Substances, Accidents and Universals: In Defense of a Constituent Ontology," *Philosophical Papers*, 26 , 1997, 105-127.

large and small fish together with a sealed aquarium inside which they are swimming.

Each single cell is a substance in something like this latter sense: it has a membrane surrounding a nucleus, mitochondria, endoplasmic reticulum and so on, all of which float in an intracellular fluid.

Cells, like human beings and other organisms, are distinguished from wooden boxes, blocks of ice and similar chunks of non-living matter by the fact that they are *unified causal systems which are relatively isolated from their surroundings.* (Ingarden)

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 protecting and for reconstituting 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.

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.

The Hierarchical Structure of the Organism

Each multi-cellular organism is a relatively isolated causal system 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: the skin.

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.'

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.

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 point 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. Something similar must occur in the course of development of a human being. A given body of 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).

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 can be classified as follows (with corresponding generalizations for more complex cases):

i) *Budding* (of the Republic of Ireland from the United Kingdom): 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.

ii) *Absorption* (of DDR by BRD): A smaller object becomes absorbed into a second, larger object in such a way that the former undergoes a substantial change and thereby ceases to exist. 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* (CS): 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 constitute 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. Fission gives rise to new entities and destroys the entity which existed earlier. An amoeba, for example, 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.

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 a (more or less perfect) union.

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 briefly 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.[3] 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'). 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). 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 tissues.

Gastrulation. When the foster is fully implanted in the wall of the womb (day 13), it

[3]V. Gaddis and M. Gaddis, *The Curious World of Twins*, (New York: Hawthorn Books, 1972), pp. 30 ff., W. R. Mayr et al., "Human Chimaera Detectable only by Investigation of Her Progeny," *Nature* 277 (1979), 210-211, and Gilbert *op. cit.*, pp. 186 ff.

is for the first time able to receive nutrients from the mother. 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.

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 epithelia, 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.

The umbilical cord is an organ of the fetus that penetrates the placenta via two large arteries which radiate outwards from the point where it breaks through into the inner surface of the placenta. These divide into small 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 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. Around the sixteenth week hair also begins to grow and teeth are developed. At the twentieth week, the foster 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 thereabout, it is born.

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 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. Neurulation (from day 16)
h. End of first trimester (day 98)
i. Viability (around day 130)
j. Quickening (around day 150)
k. Birth (day 266)
l. 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. The two cells inside the thin membrane are then not one but rather two substances. The two-zygote whole is, in our terminology, the result of a substantial change.

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. 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 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 no flow of nutrients or signal molecules from the outside to the inside of the membrane or from one cell to another, and 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.

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. 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 receive nutrients from the mother and it can begin to grow as an individual and to 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 here at issue. An identification of the foster with the later human being faces now however the additional problem that the foster 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. It is important here to 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 symmetry and its own mechanisms to protect itself and to restore stability in face of disturbance. 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 for the first time a bona fide spatial boundary which delineates the embryo spatially from the extraembryonic tissue.[4] 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. 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 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 the sole candidate singularity in the process of neurulation which might be of significance for the ontological status of the foster (for example as a bearer of moral significance) 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. 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.

i. 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

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

proper function within the locus of its proper encompassing environment. The problem with this view, however, is that the transition to viability does not in itself connote a transformation of one entity into another. Rather, it may represent a mere Cambridge change of the sort which may be expressed by a proposition such 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.

j. 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.

k. Another alternative is 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.

l. The final alternative is that it is the acquisition of some extra feature which marks the beginning of the human individual. This extra feature is that which makes the foster a human being. One obvious candidate (at least since Locke) is consciousness, and in particular self-consciousness.[5]

Can we, then, identify the acquisition of the capacity for self-consciousness (or of some similar capacity) as marking the point when the human being begins to exist? Such a dispositional property requires in every case some underlying real 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 l. 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. 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. 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 the transition to consciousness that would likewise constitute a substantial change in the organism considered as a whole.

The principal argument against alternative l., however, as also against alternatives h. through k., 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.[6]

Twinning

Even if it can be definitively established that there exists a human being at the stage of gastrulation, however, this still leaves open 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)

[5]Compare B. Brody, *Abortion and the Sanctity of Human Life: A Philosophical View*, (Cambridge, MA: MIT Press, 1975), and M. Tooley, *Abortion and Infanticide*, (Oxford: Clarendon Press, 1983), p. 167. Tooley argues that the life of the relevant entity begins when it has the capacity to care about its own continued existence.

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

into two or more entities which are similar to themselves. 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). This of course is not a logical but rather a biologically impossibility

They satisfy 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.

Plants and fungi can divide to form new individuals because their cells are relatively undifferentiated. By the end of gastrulation, however, the foster has gradually 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 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 alternatives must now be considered. On alternative (1) one of the two parts of the foster is transtemporally identical to the human being that will exist after birth. On alternative (2) identity applies rather to the foster as a whole, as it exists in a phase when twinning via separation is still possible.

Alternative (1) can be rejected on *a priori* grounds. First, it implies a peculiar scenario under which 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.

Alternative (2) 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 into two parts was still possible. The United States was then actually one but potentially two. But separation did not in fact occur. Must we not then say, by parity of reasoning, that the

foster, at the stage when twinning via separation is still possible but does not in fact occur, 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.

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 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 allows us to identify the relevant substantial change as occurring at the very end of the sixteen day period.

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.

The problem we face in formulating such a condition 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).

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.[7] 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

[7]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 B. Smith and A. C. Varzi, "The Niche," *Nous*, 33 (1999), 214-238.

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 our twelve conditions 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 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.

Is the Foster Connected to the Mother?

Is the Foster a Part of the Mother?

Schluss: The Birnbacher Argument

But surely, it might be argued, all natural change is continuous.[8] 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.

[8]This is argued in Birnbacher, *op. cit.*