Early Embryonic Morphology and Its Changing Forms

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Abstract: The view upheld in this article is that the embryo is a unique living being that starts life in this dimension as a zygote and goes through a process of morphological differentiation that involves various forms. This process of somatogenesis (formation of a body) appears to follow the principle kingdoms of nature showing reminiscence of the mineral, plant, animal, and human phases, a process it shares with all human embryos. The characteristic "way of being" of the organism during each phase is also presented. An historical background to other early theories involving somatogenesis and evolution is outlined.

Key Words: embryo, living being, morphological differentiation, somatogenesis, kingdoms of nature

The process of somatogenesis (formation of a body) is not without its conflicting opinions, particularly because it involves theories related to embryogenesis and evolution. However, as it appears that early theorists were only talking about a certain phase of somatogenesis and not the entire early process, I suggest that these theories need to be reconsidered. This becomes more obvious when we realize that Oscar Hertwig only proved that fertilization was due to fusion of an egg and sperm cell in 1876 (Clift & Schuh, 2013). This was after Darwin's book *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life* was first published in 1859. This makes it more understandable why early theorists like Darwin (1859), Haeckel (1866) and Lamarck (1809) did not include in their theories the earliest forms that we now know can be observed during the process of somatogenesis, namely the zygote and the phase involving implantation.

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As these early theories still influence our thinking today, I briefly outline the historical background of the role embryogenesis has played in theories involving evolution. Based on these considerations I propose that we revise our understanding of the nature of evolution and somatogenesis to include the considerations presented in this article. I justify this on the grounds of the new understanding it brings regarding the nature of the embryo, which is also our nature. “Facts are not impartial, but a perceptual content is always intertwined with interpretation“ (van der Wal, 2003/2014, p. 9) and the approach adopted here is no exception.

The view presented is inspired by the dynamic morphological approach applied by the embryologist Jaap van der Wal as well as the novel way the cardiologist Torrent-Guasp (2011) unraveled the human heart. The insights arising from the work of these two scientists help us to understand the morphological development of the embryo as a unique entity: a living “being“ whose ontogenesis “mirrors the four main phases of the development of humanity as a whole - phylogenesis“ (p. 30). Interestingly, the four main phases the organism undergoes is reminiscent of the main kingdoms of Nature: the mineral, plant, and animal, to which van der Wal (2003/2014) adds a forth, the human phase.

Torrent-Guasp´s (1973) method of dissecting the heart reveals that the ventricular myocardial band of the heart has a helical configuration and the unique folding of the myocardial band during embryogenesis follows the evolution of the cardiac morphology from worms to mammals. This process is mirrored by the development of the notochord and central nervous system (CNS).

The basis of many of the insights discussed in this article arise out of observable data not experimental data. Modern technology plus the collection of embryos such as those of the Carnegie Stages[1] have made a previously invisible process accessible to scientific scrutiny.

Historical Background

Embryogenesis has historically played an important role in theories involving evolution. Some of the early scientists interested in embryology were Lamarck (1809), Darwin (1859) and Haeckel (1866), although their conclusions concerning the evolutionary process are not the same.

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[1] "Human prenatal development is divided into an embryonic period and a fetal period. The embryonic period begins with fertilization and ends eight weeks later. The staging of human embryos was introduced in 1914 by Franklin P. Mall at the Department of Embryology of the Carnegie Institution of Washington. Mall's successor, George L. Streeter, later refined the classification of human embryos into 23 stages, or 'developmental horizons'.
It is important to note that each of the 23 Carnegie stages represents an arbitrary point along the time-line of development, akin to a ‘freeze-frame’ in a movie. The stages are based on a variety of morphological features and are independent of chronological age or size" (The Virtual Human Embryo, 2011a)

Haeckel's theory supported Lamarck's theory of acquired characteristics. However, Haeckel was also progressive in that he felt evolution followed a specified path from lower to higher animals. In this respect, Étienne Serres (1824-1827), the French physician and embryologist, and Johann Friedrich Meckel (1811), the German anatomist, also influenced him. Although these two scientists worked separately, others joined their ideas in what is known as the "Meckel-Serres Law" (O'Connell, 2013). This law is based on a belief that within the entire animal kingdom there was a single unified body-type, and that during development, the organs of higher animals matched the forms of comparable organs in lower animals. "The concept that the embryos of higher order organisms progress through successive stages in which they resemble lower level forms is called recapitulation" (O'Connell, 2013, para.1). This theory was later criticized by van Baer (1828) on the grounds that there was not only one single chain of life, but that the animal kingdom could be divided into four distinct archetypes, or fundamental body plans: the radiate, like the starfish; the *mollusca*, like clams and octopus; the articulate, like insects and lobsters; and the vertebrata, like fish and humans. After this criticism, the Meckel-Serres Law lost popularity. However, when Darwin (1859) argued for a common descent among species in his book, *On the Origin of Species,* Haeckel was prompted to resurrect the main points of Serres and Meckel's theory (O'Connell, 2013). Haeckel incorporated a modification of their ideas and that of Lamarchism and Darwin into his biogenetic law (Barnes, 2014) as on this basis, Haeckel felt evolutionary trees could recapitulate phylogeny. This law claims that the development of advanced species passes through stages represented by adult organisms of more primitive species, which Haeckel also expressed as "ontogeny recapitulates phylogeny" (1866). However, Darwin disagreed with Haeckel's idea of a progressive evolutionary theory as he considered that species sharing a common ancestor would look alike even though they might belong to different taxonomic groups. Haeckel's law was also discredited by later scientists on several grounds: it was suggested that he had exaggerated some of his drawings indicting similarities between species (Wellner, 2014), ontogenic stages only represent more general characteristics of a taxonomic group and not the specialized forms of the adult animals (van Baer in Barnes, 2014), and experimental evidence from early twentieth century embryologists. However, these criticisms do not do full justice to the impact of Haeckel's influence on human thinking. He coined and introduced many new concepts, the most notorious being the already mentioned concise phrase "ontogeny recapitulates phylogeny" (1866).

None of these theorists mention other observable earlier features of human embryological morphological development such as the zygote and the phase involving implantation and only contemplate the features that appear when the endocyst (inner egg), comprising of the germinal disc, starts to develop. This tendency continues today with the germ disc being considered as the "actual embryo" and the ectocyst as being "extra-embryonic" (van der Wal, 2003/2014, p. 43).

Later embryologists took a different approach. Darwin's half cousin, Francis Galton, connected genetic influences to Darwin's theory in his famous book, *English Men of Science: Their Nature and Nurture* (1875). This connection changed the focus of interest from observable forms to factors responsible for the forms. It also gave rise to the nature versus nurture controversy, where nature is represented by genetic factors and instincts, and nurture by a wide variety of environmental influences. Together, they are said to have an influence on anatomy and on behavior, also referred to as structural and functional aspects.

These theories gave rise to tremendous bursts in science and helped explain many factors including genes and how they work. More recently the role of epigenetic factors in gene expression is becoming increasingly relevant (Nilsson & Skinner, 2015; Riggs, Russo, & Martienssen, 1996; Skinner, 2014; Torday & Miller, 2016). This does not mean, however, that these theories are the only theories that can throw light on embryogenesis. Changing the perceptual context, as stated earlier, changes what is seen.

In this article, we will return to look at the morphological forms observed during somatogenesis, including the earlier forms not mentioned by Lamarck, Darwin and Haeckel because they were not known to science at the time these scientists were putting forward their theories. Here the "actual embryo" is seen as comprising of the zygote and both the ectocyst and endocyst, an approach adopted by the embryologist Jaap van der Wal (2003/2014).

The Process of Somatogenesis

According to Van der Wal (2003/2014), the embryo goes through four distinct phases during its ontological development, a process shared by all human embryos. During these phases the morphology of the human embryo becomes increasingly more complex. This increase in complexity, however, does not imply an increase in what the embryo is: a living being. This is in keeping with Blechschmidt (2004) who stresses the preservation of individuality of the embryo. During the progression of each phase, slight changes in expression in the form can also be observed which suggests that the whole process is essentially dynamic. What "changes during development, is only the phenotype but not the essence. … In short, a fertilized human egg (conceptus) is already a human being" (p.8). Although the human egg contains species-specific chromosomes and the genetic material remains the same during the entire life of the individual, Blechschmidt questions the theory that the structure of the human body is based on information contained in the genes. "As each cell is equipped with identical genes, the genes themselves would have to know by themselves on the basis of information how, where, and what differentiation should occur, in each split second, in every part of the organism, during the whole of organism's life" (p. 16). For this reason he suggests the "form of the organism differentiates under biodynamic forces, not chemical-genetic information" (p. 18).

Although Blechschmidt has an influence on van der Wal's approach, the insights of O.J. Hartmann (1945) regarding the four natural kingdoms and the changes in the relationship of the center (point) to the periphery, seem to play an even greater role. For Hartmann (1945), each phase is seen as being in the opposite direction to the dynamics of the previous phase. "So the dynamics of the plant are not brought about by the mineral, they are not a continuation or 'more of the same.' A new principle manifests in the plant which stands in direct opposition to the mineral" (van der Wal, 2003/2014, p.34). Hartmann's insights are built on and extended by van der Wal in his theory, which is summarized below. Here we do not go into van der Wal's account of the different etheric bodies.

The Different Phases

a) The Mineral Phase: After conception, the fertilized ovum is no longer a cell, but a zygote, a living organism. Van der Wal likens the spherical form and behavior of the zygote to a "mineral" for it, too, has a protective outer shell and splits into ever-smaller segments on the inside. This phase lasts one week and if no new principle is introduced, the organism will die off. In humans, many miscarriages occur at this point, often without the mother even knowing that she is pregnant.

b) The Plant Phase: This new phase involves implantation, also known as nidation. During this new phase the ectocyst (outer egg) reaches out and extends its boundaries deep into the maternal womb. It can be considered to be *plant like* for, like a seed, it first takes *root* and has a center, the bilaminar germinal disk, which is not initially involved in growth. However, if this tendency continues, it will not aid growth, but produce a "wind egg," an embryo without a center. This can be very difficult for the mother as she has a full experience of pregnancy. At the end of the plant phase, the chronic cavity comes into being as well as mesoderm, a tissue that connects and mediates between the two dimensions by means of the body stalk. Blood islands and blood vessels (capillaries) arise in this extra-embryonic mesoderm allowing blood to flow from the metabolic periphery of the trophoblast, or extra-embryonic mesoderm, to the body stalk, which is at the caudal end of the germinal disc. It then proceeds toward the cranial end of the embryo, running alongside the “flanks“ of the germinal disk, then dorsally along the amniotic cavity (only very little) and ventrally along the yolk sac (some more). At the central point, which van der Wal (2003/2014) calls the “centripetal junction of blood vessels,“ it comes to a halt and then flows back to the periphery through other capillaries. “This point of reversal, where the flow comes to a standstill, turns about, and takes on a rhythmical character, is the first indication of the origin of the heart“ (p. 44).

c) The Animal Phase: On approximately Day 17 the point of reversal of the blood vessels at the cranial end of the germinal disc “takes on a rhythmical character, (and) is the first indication of the origin of the heart“ (van der Wal, 2003/2014, p. 44). The heart *primordium* now doubles and begins its descent towards the thoracic region at the base of the yolk sac where it later tucks the endocardinal tubes ventrally (Richtsmeier, 1999). Here pulsation can be considered as heralding a new phase. The same day the heart *primordium* starts pulsating the notochord starts to form (Moscoso, 2009). With the introduction of mesoderm via the body stalk, the flat germinal disk first transforms into a trilaminar disk from which the impulse for forming organs later arises (van der Wal, 2003/2014). During the 3rd, but primarily the 4th week, a process known as folding or delamination starts to occur. The sides of the embryo, which up to now have been essentially a flat trilaminar disc, now fold toward each other. At the same time there is a longitudinal folding which together transforms the now three-dimensional embryo into the form of a cylinder. The longitudinal folding takes place toward the body stalk, which enables the developing embryo to still be connected to the placenta. The process whereby the heart descends form the top cranial end of the germinal disc allows the brain primordium to later take its place. During this process, the caudal end also raises ventrally, which now truly gives rise to the umbilical cord. This curving process of the embryo creates an inner world, which is essentially cut off from the outside world. It is in this inner world that the organs develop.

d) The Human Phase: Van der Wal (2003/2014) also distinguishes humans from animals in that although both have “innerness,“ in animals “the center of gravity is on the outside and pulls the animal away from itself towards the earth“ whereas in humans their center of gravity is on the inside. The human is the only animal capable of coming upright. Whereas the animals “inner life is undirected, the human has a center towards which inner life orientates itself“ (p.33).

"Ways of Being" of the Organism During the Different Phases

During the process of somatogenesis the organism not only takes on different forms but van der Wal (2003/2014) associates each form with certain characteristics. During the mineral phase the organism is a closed system that follows the laws of matter, of physics, and mechanics and can be seen as existing in space but outside of time for, although it lasts a week in mammals, it is not counted in the number of days or months regardless of the duration of the pregnancy. Growth is initiated from the invisible spherical center from which cleavage arises, first into two, then four, then eight, and so on in a geometrical way. As this phase progresses, it splits into increasingly smaller parts. Eventually the particles in the center start to die off and a cavity forming liquid forms in their place. It seems here we can talk about implosion where denser and more condensed particles collect around the periphery (trophoblast) meanwhile others reach towards the center (embryoblast).

> *The "way of being" of the organism during the mineral phase may be seen as one that is guided by forces of "matter, physics, and mechanics"* (p.31).

In contrast to this, the plant phase can be seen as having different characteristics or giving rise to a different "way of being" which involves implantation and if we are reading "this gesture correctly... [this] represents an interruption, a revolution" (van der Wal, 2003/2014, p.36). It is characterized by expansion from a point where some of the peripheral cells of the free-floating mineral become connected to the mother´s womb. At the same time, the embryo extends its "roots" deep into the maternal blood system, although the blood systems of the two organisms do not actually join. This phase is characterized by openness, reaching out to the environment, the multiplication of cells and connection and expansion of its boundaries. It seems here as though we may talk about explosion. Furthermore, by producing the hormone of pregnancy, it reaches into the pituitary gland of the mother, which facilitates her acceptance of the new organism. From being a cut off "space ship"(van der Wal, 2003/2014, p. 36), the periphery of the organism now expands tremendously and reaches far beyond its physical borders. The way of being of the organism during the plant phase may be seen as one of expansion of its boundaries in a physical and metaphysical sense. It exists in time and is subject to the laws of gravity and strives against them.

When we then compare the way of being between the plant and the animal phase we find another change in form and way of being where growth starts from a center at the cranial end of the germinal disc (endocyst). This center takes on a rhythmical pulsation, which is tangible, the importance of which we will discover later. One of the chief characteristics of this stage is inner growth for instead of growing upward and outwards like a plant (Lindhard, 2016) growth is now internal and downward. During this animal phase the organism has an inside but is also affected by the exterior or outside, with which it has a relationship and is closely connected. The way of being of the organism during the animal phase may be seen as one of innerness, which permits the establishment of a relationship with the outside environment. It is mobile and exhibits a range of complex behaviors. It is also sentient and possessing perception.

Van der Wal (2003/2014) finds a new turn about during the next growth phase that distinguishes humans from animals. The upright anatomical structure of the humans permits a change in the center of gravity from outside to inside the organism. In the beginning of the fourth and extending into the 5th week, an impulse that starts with the elongation of the brain and not only “brings about the characteristic flexures of the different parts of the brain,“ but also “the head grows cranially away from the trunk, whereby the neck appears (p. 50). At the same time, “the pelvis ‘turns‘ caudally ‘away‘ from the trunk coming under it, resulting in the waist being formed“ (p. 50). This permits an awareness of not only the outside, but also the self; the organism can become aware of its awareness, it can become aware of its self. The way of being of the organism during the human phase may be seen as one where human beings can become aware of their inner world and experience “a center in ourselves“ (van der Wal, 2003/2014).

It is this that enables the human being to later undertake an inner journey to discover their true nature or Self (Arka, 2006; Lindhard, 2016; 2017a; 2017b).

The Relationship Between Phases

To go beyond the reductionist Newtonian method, van der Wal (2003/2014) uses a way of seeing which is known as “dynamic perception“ (p. 3). This is inspired by the phenomenological method of Goethe and it involves the juxtaposition and observation of two isolated but polar objects. Through this, one can begin to see “more of the essence of the separate parts.“ At the same time, one starts discovering the “phenomena, which remain hidden whilst focusing on isolated parts...In other words one develops an eye for the total picture“ (p. 2).

Using this method, van der Wal (2003/2014) suggests that each phase is the polar opposite to the one before. It is turned “inside out.“ He stresses that these qualities are not opposites in the conventional sense, for it seems they have a “shared essence, being present beyond the polarities under consideration“ (p.4). When one looks at what unites the two parts, van der Wal proposes that it is rhythm and that "polarity exist ... within a unity" (p.15).

Morphological Development of the Heart

In order to understand the heart's morphological development we first have to consider the unique way it is folded. Through blunt dissection, Torrent-Guasp discovered it was one continuous strip, known as the helical ventricular myocardial band (HVMB): the heart is folded into a structure resembling a double helix (Torrent-Guasp et al. 2001). As pointed out earlier the morphological development of the heart follows "the evolution of the cardiac morphology, which occurred in millions of years from worms to mammals" (Corno, Kocica, & Torrent-Guasp, 2006, p. 562). In 20-day-old embryos, the heart is first a single vascular tubular structure *like a worm*. The next stage, which occurs at 28 days, is fish-like, developing into a sequential pulsatile pump including the atrium, ventricle, *bulbos cordis* (*conus*), and *truncus arteriosus*. At 30 days there is a further change with the heart resembling that of reptiles and amphibians in that it has two-chambers with atrial and ventricular septal defects. And finally, between 35–50 days, a four-chambered structure appears which is what is found in birds and mammals (Corno et al, 2006)

Further work on the heart by Torrent-Guasp and others (Kocica et al. 2006) led them to regard the three-dimensional ventricular architecture as a geometrically non-orientable surface similar to a triple-twisted Möbius strip, indicating it might have a relationship to the three phases already mentioned.

Development of the Notochord and CNS

If one concentrates purely on the development and descent of the heart, one misses the other activities that are happening at the same time in the embryo's body, which indicate we are talking about an undivided whole. On day 17 of post-fertilization the *primordium* heart begins to pulsate and the notochord, a cartilaginous skeletal rod supporting the emerging body, can first be observed. The notochord is fully formed by the 25th day (Moscoso, 2009) and arises out of mesoderm tissue, which although it was already present in the ectocyst or peripheral body (van der Wal, 2003/2014) now comes into being in the endocyst.

The first task of this primitive mesoderm is:

> To come together to form a long cylindrical structure. In doing this, (it is) recapitulating the earliest event in the transition from

> invertebrates to vertebrate forms, a transition which occurred at least six hundred million years ago. This rod-like structure is the notochord, the progenitor of the backbone or vertebral column (Scheibel, 1997, Appearance of the Notochord section, para. 1).

The notochord extends throughout the entire length of the vertebral column and forms the longitudinal axis. During a process known as neurulation, the notochord influences the ectoderm to first form the neural plate, which then folds in on itself to form the neural tube (Ladher & Schoenwolf, 2005). This process takes place over several days starting day 18/19. The embryo at this stage is not straight but "tubular" (Moscoso, 2009. p. 14).

During this development, the embryo first resembles that of a worm with its flexible notochord; then it grows pharyngeal arches, which later disappear. This is followed by a tail (The Virtual Human Embryo, 2011b), which later begins to atrophy round about day 41 to 44. When the four-chambered structure found in birds and mammals slowly starts appearing, one can observe interdigital zones that form into hand plates with visible finger radiations and footplates where the toe *primordium* becomes visible (The Virtual Human Embryo, 2011c). Then at Carnegie stage 20, when the embryo has a length of between 18 to 22 mm and an estimated post-fertilization age of approximately 49 days, one can observe that the upper limb has become longer and slightly bent at the elbow. "The hands are still far apart and the fingers are short, stubby and slightly curved over the cardiac prominence. The interorbital groove is conspicuous" (The Virtual Human Embryo, 2011d). The embryo now has a more human like appearance. The anatomical-morphological development of the human embryo permits the embryo to unfold. Coming upright, as we have already seen, permits the center of gravity in man to be inside the body, which allows humans to experience a center inside of themselves (van der Wal, 2003/2014).

The neural plate, neural tube, nervous system and the brain are formed from ectoderm cells (Scheibel, 1997). "At organ level, brain development starts with the formation of the neural tube or neurulation, followed by formation of the neuronal migration and neuritic differentiation, with synapse formation and controlled neural 'pruning'" (Bourgeois as cited in Moscoso, 2009, p. 13).

The Heart and Pulsation

The development of the heart and the development of the notochord, including the CNS and the brain, are parts of an entangled whole. Dividing the body into different systems is quite artificial. "Body systems do not exist in reality–it is always impossible to define where one system ends and the next starts“ (Blechshmidt, 2004, p. 2). However, like van der Wal, we can ask what is the underlying principle or principles that unite this development (Lindhard, 2016).

Looking at the multifunctional role of the adult heart, Burleson and Swartz (2005) hypothesize that the heart functions as a generator of bio-information that is central to normative functioning of body. The source of this bio information is based on: (1) vortex blood flow in the left ventricle; (2) a cardiac electromagnetic field, as well as both: (3) heart sounds; and (4) pulse pressure which produce frequency and amplitude information. Thus, there is a multidimensional role for the heart in physiology and bio-psychosocial dynamics.

Their hypothesis, which is based on the four criteria mentioned above, looks at the role of the heart in maintaining normal body function. They mention heart sound as being one of the factors. Rubik supports this by suggesting that body functioning might include “acoustic and possibly other subtler energy fields not yet known to science“ (Rubik, 2009, p. 555). Although these researchers are talking of body functioning, some of these criteria such as heart sounds, which are related to pulsations, could also possibly play a role during somatogenesis. This is obviously not a complete answer, but it is possible that the development of form takes place in phases or waves, which are guided by rhythmical pulsation (Lindhard, 2016, 2017b).

Conclusions

Each embryo is a living being and is unique. However, during its ontological development it goes through various phases, which are common to all human embryos. The descriptive approach adopted towards somatogenesis in this article forms a basis from which further investigation may proceed and we now need to establish the dynamics and forces behind the formation of the different phases. Here we have followed van der Wal (2003/2014) who suggests that somatogenesis is a process that is dynamic and that each different phase is a polar opposite to the one before. Whereas he suggests that it is rhythm that unites the phases, we have clarified this further by suggesting that it is possible that the development of form takes place in waves, which are guided by rhythmical pulsation.

It is possible that the forces involved may come from Higher Nature, considered sometimes as an overriding intelligence behind all matter, the environment, and/or the developing organism itself. It seems possible that these forces will also involve electric and electromagnetic forces (Lindhard, 2016). This is consistent with the work of Burr who was one of the first scientists who was interested in the relationship between electric fields and life. Using microsurgical instruments, Burr (Burr & Hovland, 1937) established that in unfertilized eggs of various species, the place of maximum voltage would, after fertilization, correspond with the head of the organism and the place of minimum voltage would correspond with its tail (Burr & Hovland, 1937; Matthews, 2007). Although we know genes are also involved, we still need to know at what stage they kick in and what role, if any, they play with regards to the phases outlined here. They also probably interact with these other forces and we need to find out how this is done. It is recognized that "what mothers eat, drink, and feel—the environments which they themselves experience—affect daily the neural development of their unborn child" (Scheibel, 1997, para. 1). So how these environmental factors interact with these other mentioned forces is important, not only to increase our understanding, but also to ensure healthy babies and healthy individuals.

The perspective adopted in this article also opens us to the main metaphysical question behind most spiritual traditions: "**who am I**?" Far from trying to answer this question, I limit myself to say that our embryonic past seems to point to the fundamental mystery behind our existence. There is much still for scientists to discover which will not only help us understand the development of the embryo but possibly the nature of Nature itself, for the embryo can be seen as a miniature of the Universe (Lindhard, 2016, 2017b).

As we have shown here, we have been through various phases during the first approximately 49 days of our embryonic existence. This process also indicates that during our embryonic history, we have already taken different forms and to evolve and grow, we had to "die" to the each of the previous phases with their corresponding "way of being." This also implies that to evolve and grow we will also need to die to the form we are taking now.

In conclusion, I quote from Rumi (n.d.), the Persian poet and Sufi mystic (1207-1273):

I died from minerality and became vegetable;
And from vegetativeness I died and became animal.
I died from animality and became man.
Then why fear disappearance through death?
Next time I shall die
Bringing forth wings and feathers like angels;
After that, soaring higher than angels -
What you cannot imagine,
I shall be that.

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