CHAPTER 19

Development Writ Large

We have found throughout the preceding chapters that all biological activity, including at the molecular level, is thoroughly and irreducibly purposive and end-directed. Successive states of an organism are stages in a life narrative — a drama of progressive self-realization and self-expression. Life stories are *meaningful* in the fullest sense of that word. Significant form comes into being; inner character finds exterior expression; processes form out of implicit intentions; needs and interests trigger pursuit of means for their satisfaction; injury leads to an effort of healing; ends correspond to initiatives. Physical causes and effects are *organized*, or given their form, by the meanings of a particular way of life. Few biologists explicitly acknowledge this truth of a living narrative, but all biologists implicitly recognize it in their choice of descriptive language. (Extremely relevant here are the few paragraphs contrasting a dog and its corpse in Chapter 2, "The Organism's Story".)

This leads naturally to a conclusion of this book — a conclusion I will develop in this chapter — which is that *we already know more than enough to say that evolution is a purposive, or directive or* telos*-realizing, process*. I understand that you may have difficulty coming to terms with this conclusion. But, as I hope to show, it is really just a matter of admitting to ourselves what we in fact know quite well. After all, an at least implicit recognition of the directiveness of living activity, however repressed in intellectual consciousness, is the only thing that lends to the mass of biological description and theory any appearance of plausibility. ("This cell is dividing; that cell is replicating its genome; this other cell is engaged in a deliberate process of self-destruction; just about all the cells in that lioness' body are in one way or another supporting its effort of running at top speed in pursuit of an antelope". Can we avoid assuming, in one way or another, that the molecules in all these cells are fully informed by their context, so that they "know" what to do?) Organisms are beings whose lives give purposive expression to their own needs and interests, in accordance with their own character.

Living beings, in other words, are quite unlike inanimate things, which don't have needs and interests and don't carry out directive tasks. Whether consciously or unconsciously, every organism directs its actions toward the future. An unmet need leads to activity whereby the need can be satisfied. On our part, we find ourselves framing every organism's purposive actions within the time dimension — this despite readily seeing that most organisms themselves have no *experience* of a future contrasted with the present. We can hardly believe that a bird building its nest is consciously anticipating its future chicks.

Nevertheless — and this is a crucial observation too easily ignored in evolutionary theorizing — there is a clear sense in which the objective character of all biological activity does exhibit what, from our own standpoint, we cannot help viewing as a future-oriented meaning and directionality. Every organism's life consists of initiatives temporally correlated with ends, ideas progressively being given form, needs and interests prompting exploration — even if the initiatives and ideas, the needs and interests, never become conscious for the animal itself.

The animal's purposive narratives are so "boringly" familiar that we cannot help taking them for granted. We assume their decisive role in every biological context we look at, and cannot “un-know” them even when we are theorizing from a position that ignores or denies them. And so we have the two paradoxical sides of biology today: an uneasy, theoretical disregard of what seems ungraspable or dangerously mysterious or unable to be captured in purely physical terms; and a carefree, unexamined taking-for-granted of the powers so obviously at work in those all-too-familiar mysteries — powers that unconsciously inform our scientific thinking and only by this means enable us to believe that our purely physical, cause-and-effect theorizing actually makes sense.

My aim in this chapter — an aim grounded in all the preceding chapters — is to facilitate the changed angle of vision that can enable readers to grant full recognition to what is already known.

Evolution as a transformation of developmental processes

Few developmental biologists will dispute that a wolf’s development, proceeding from a fertilized egg cell through embryonic and fetal stages to the pup’s birth, and then on through life to maturity, is highly directive. It is an improvisationally coordinated, inherently meaningful, and adaptive movement emerging out of the past while oriented toward the future. It is part of an ever more complete self-expression by the being we know as a wolf. We would never say of a geyser or meteor that it is, in this sense, moving toward fuller self-expression.

Yes, a wolf’s development is a path full of unpredictable variation, never exactly repeated in different wolves. But this makes it all the more impressive that the entire trajectory remains persistently wolf-like despite all the adjustments to disturbances and despite all the adaptations to changing conditions — and also, despite the wolf’s feeding day after day on the flesh of other animals, which it never fails to convert into its own flesh and way of being. The individual wolf, embedded within its physical and social environment, exhibits the organizing power of its species, and remains throughout its life capable of negotiating a wolf-like path through the uncertainties of its existence.

The three-week-old heart of the unborn wolf is dramatically different from that of the six-week-old heart, which in turn differs from the heart immediately following birth (at about nine weeks), and this again differs from the heart of the mature wolf. It is presumably uncontroversial to say that any biologist who studies wolf physiology and development (something you can be assured I have never done myself) will expect the processes leading from one stage to another to show all the features of organic activity.

Organic causation is inescapably holistic: a change in one part of the heart can happen only together with change in other parts, so that context-dependence is a theme in all physiological, morphological, and behavioral explanation. Change is never anything less than transformation of a whole. Everything proves thoroughly directive, plastic, and adaptive, with earlier features serving as an effective preparation for later ones.

"Effective preparation" here does not refer to a machine-like necessity by which earlier stages automatically determine later ones. Instead, it's rather as if, at each moment, reference were made to contextual *meanings*, so as to guide the current activity in light of those meanings — meanings that are continually being elaborated further.[1]

Actually, it's easy to recognize this process of ever fuller revelation when we consider our own lives. For example, when we are writing a scientific paper, the sentences we have already written do not determine the next sentence. Instead, we have to keep the overall flow of meaning in mind, and then make a creative effort — we might call it an *effort of origination* — in formulating the next sentence. Something has to come freely, without necessity or physical cause, but rather in tune with a governing meaning to which we are trying to remain faithful (even if we are still in the process of trying to grasp it).

This required activity of origination remains more or less conscious and recognizable (if we are paying attention) throughout the entire writing project. In the case of an embryo's transformation, the moment-by-moment, originative activity may be unconscious (on the part of the embryo), but it is nevertheless recognizable *by us* as outside observers. At no point can we predict the next stage based on physical necessity, but only with reference to the unfolding meaning.[2] So at the very least we can say that something is going on with the embryo that looks akin to what is going on with us when we try to write up what we have come to understand of its transformation.

As for the wolf: how can we possibly believe that there are ways to get from the embryonic heart to the mature heart via a purely mechanistic pathway *not* meaningful, originative, and directive in the sense of all development? Who can point to even a single biological example of a predetermined pathway of transformation, wholly written in the physical conditions preceding the transformation?

The heart of the evolving horse

We now switch to an evolutionary sequence, such as the classic textbook lineage of the horse and begin asking a question analogous to the one we have just asked about the wolf. How might we imagine that a heart, structured *that way* fifty million years ago in the fox-sized horse ancestor, *Hyracotherium*,[3] becomes this heart, structured *this way* in the Triple Crown winner, American Pharoah?

Can we realistically picture this evolutionary metamorphosis being achieved by processes *less* well coordinated toward a future state than the developmental transformations bridging the differences between, say, a two-month- and five-month-old horse fetus? Or *less* end-directed than we find all living activity to be?

Is there any basis whatever for us to assume that the requirements for changing the heart between two stages of an evolutionary lineage is *altogether different in character* from the requirements for changing the heart between two stages of a single organism's development? It is, after all, the heart itself that must proceed along a transformative pathway in both cases, and from its vantage point the nature of the task doesn't really change. If the heart's transformation requires all the directive, contextual, highly coordinated activity we observe during development, how could its evolutionary transformation require anything less than the same directive, contextual, highly coordinated activity?

We have no evident ground for hypothesizing that the transition between two evolutionary versions of the horse's heart could be largely a matter of accumulated accidents such as could be imposed, so to speak, "from outside" by a series of interiorless, non-directive, decontextualized mutations. By "from outside" I refer to mutations conceived as not expressive of the kind of living, unifying, thought-infused power through which a cell or organ or whole organism holds together as the kind of thing it is. We know too much about the directed character of the development and functioning of all hearts — all biological entities — to make this proposal sensible.

Challenges of the heart

Imagine the heart of a horse ancestor (*Hyracotherium*). That heart must, in a coordinated way, have participated with the lungs, the brain and its complex signaling, the liver, the kidneys, and just about every other organ, as well as the vasculature of the circulatory system, and the metabolic and specialized chemistry in the blood-suffused bodily tissues — all in order to meet the "goals" of homeostasis. These include maintenance of proper oxygen levels in the blood and tissues within narrow bounds; maintenance of the levels of carbon dioxide and other gases within similarly narrow bounds; maintenance of blood sugar levels (every diabetic is acutely aware of the dangers of elevated or depressed blood sugar); maintenance of blood flow and supply according to the differing needs of various parts of the body; maintenance of blood temperature in the face of external temperature extremes; maintenance of blood pH (acidity or alkalinity); maintenance of blood pressure; excretion of toxins and waste products; and much more.

Each of these requirements is intertwined with all the others, so that the mere attempt to analyze everything that is simultaneously going on easily flummoxes the researcher or medical clinician. But the heart's "assigned function" is to participate in all these tasks with an "eye" on how they relate to the health and immediate needs of the body — all without the benefit of blood test readouts or other diagnostic tools. And all with no conscious knowledge of the highly specialized operations in which it is involved. Yet the "knowledge" is in some sense there, fully operative, and we find ourselves willingly or unwillingly admiring the incomprehensible "wisdom" of our heart's meaningful engagement with all our bodily systems.

So it must have been for the small *Hyracotherium*. Now consider the much larger and wholly transformed heart of American Pharoah. It, too, can only have differentiated out of the zygote via the kinds of developmental processes that every embryologist is familiar with. And it, too, in addition to (or as part of) its own development, must carry out all the well-aimed and expertly calculated functional responsibilities such as the homeostatic ones we alluded to above. It achieves this, not through a master control room such as we might find in a jet airliner's cockpit or a nuclear power reactor, but rather through immediate, "expert" participation in the whole body that it somehow "knows" well, without any of the training of a jet pilot or reactor operator.

So can we really think that the one heart might be transformed into the other except by means of the same play of wisdom and the same global coordination of “impossibly” intricate processes such as we see separately in the development and functioning of these two hearts? Dare we suddenly step back from all we know about the two hearts and try to imagine an intervening evolutionary process lacking the wisdom, the powers of purposive coordination, and the future-oriented performance without which neither of the hearts could exist? What justification can we find for abandoning the living picture in that way?

My point is that, once we have noticed the character of all biological activity, it’s impossible to imagine a mechanistic, accident-ridden, non-directive, mutation-based, evolutionary transition from *Hyracotherium* to American Pharoah. We can, of course, try. But this immediately violates everything we know about actual organisms and hearts. An organism makes each of its parts and each of its traits an expression of the whole it belongs to. *The part comes into existence only as such an expression. It has no separate, de-contextualized, existence of its own*.

Not nearly enough attention and reflection has been given to the seemingly impassable gulf between a mere mutational rearrangement of genetic particles (as these are mechanistically conceived), on one hand, and, on the other hand, the functioning of a complex organ intimately expressive of a whole organism while also capable of purposively and expertly pursuing all the ends so efficiently carried out by the heart. Trying to bridge that gulf between discrete particles and the meaningful unity of an organism and all its parts looks rather like the frustrating effort of cognitive scientists to bridge the gulf between matter and mind. We might in fact wonder whether the two gulfs are one and the same.

If we take seriously the truth that a living transformation is always the re-forming of an integral whole in the sense that there are no separate parts pursuing an isolated existence, then the idea of a non-organic accident that merely acts physically upon a tissue or organ without participating in its living, transforming, purposive unity has no place in our picture of evolution.[4]

Evolutionists should not forget the directedness of biological activity

The processes of organic transformation, which we observe in endlessly different contexts, just are what they are. For centuries biologists have recognized the distinctive character of these processes as definitive of life. How is it that we forget the directedness of biological activity as soon as we turn to evolution? How is it that, when we imagine the matings, predation, hybridization (see below), and other activities yielding an evolutionary transformation of the mammalian heart, we forget the ways in which cells in disparate parts of our own developing bodies must live, die, and transform themselves in a manner governed, not by their immediate physical necessities, but rather by the emerging form of a body that does not yet exist — a body that belongs to a future from which no physical causes are able to act?

It is, after all, the whole nature of a developmental narrative to proceed directionally and seamlessly *from here to there*. It would require a powerful and unexpected set of arguments to show that nature, employing any conceivable set of historical processes, could effectively transform such a developmental narrative otherwise than by entering into and respecting the terms governing all such narratives. The need is to improvise as necessary while managing a frightfully complex, systematic, re-organizing, future-oriented activity that is the only basis for developmental transformation we have ever witnessed in organisms.

Figure 19.1. An artist's conception of the fox-sized horse ancestor, *Hyracotherium*, in the Natural History Museum of London.[5]

The racing champion, American Pharoah, is as remarkable an endpoint for the evolutionary trajectory from *Hyracotherium* as it is for the developmental trajectory from its own zygotic stage. If we can hardly help taking for granted the directive activity required for the latter sort of development, can we find any justification for overlooking the necessity for directive activity in the former sort?

Figure 19.2. Triple Crown winner, American Pharoah.[6]

Or again: If evolution employed fifty million years and countless generational inheritances and matings (and much else) to accomplish the transformation of the *Hyracotherium* heart into the heart of American Pharoah, is this likely to require *less* directive oversight than what is so visibly evident in the development of American Pharoah's maturely functioning heart from its embryonic stage?

Remember what was perhaps the main point of Chapter 18 ("Teleology and Evolution"): the decisive issue is whether we are willing to acknowledge explicitly the directed character that everyone implicitly recognizes in an individual animal's development. If we do acknowledge it, then the present argument is in part that nothing further needs to be assumed in order for us to recognize an analogous directive aspect in evolutionary change; we are watching a coherent process of organic transformation in both cases. If we do not acknowledge it, we are left with what would appear to be the hopeless mystery of the developmental process.

A thought experiment

Let’s assume that horse-racing enthusiasts never stop breeding horses. We’ll assume further that, having magically transported ourselves into the future, we are holding in our hands the exhaustive, generation-by-generation, molecular-level and phenotypic documentation for a thousand-year evolutionary lineage running from the 2015 Triple Crown winner, American Pharoah, to the greatest mega-champion of all time. Call him Chinese Ceasar if you wish.

It is a safe bet that Chinese Ceasar differs significantly from American Pharoah. The specific differences will depend, among other things, on the qualities that breeders valued throughout those thousand years — running speed presumably being one of them. Due to the principle of holism, through which a change in one feature of an organism is linked to change in many others, it is hard to imagine what sort of horse we would be looking at a thousand years from now. But surely it would be a horse of a different color.

Surely also, this would be a case of *directed* evolution — “directed”, not merely in the usual biological sense, but also in the sense of “intended by breeders”. But *would we recognize this fact if we were unaware of the breeders’ role?* That is, could we discover, solely from the horse lineage itself, the fact that it progressively realized certain ideas, or guiding principles, or intentions?

The question seems to me important. Strongly held opinion has it that actual evolutionary history shows no directive or progressive aspect — not, at least, in an intentional sense bearing much resemblance to the directionality imposed by breeders. But if the answer to our question is, “No, we wouldn’t necessarily be able to recognize Chinese Ceasar as the result of directive evolution”, might the reason be that all evolution is directive, and we have no contrasting experience of any other sort with which to compare our observations?

We might also put the question this way: If, in fact, we have not yet found a way to distinguish the features of a directive evolutionary lineage from those of a supposedly non-directive one — then on what grounds has there arisen the consensus claim that normal evolution is not directive? Have we, all this time, been speaking of “non-directive” evolution while unconsciously assuming all the features of a directive evolution?

If I am not mistaken, then, here is a fair request we can make of evolutionary theorists. Show us how we might distinguish, at least in principle and in the metamorphosing organisms themselves, a non-directive evolutionary process from a directive one. Or, if you cannot do this, then explain the evidence upon which you have concluded that evolution is, in general, nondirectve.

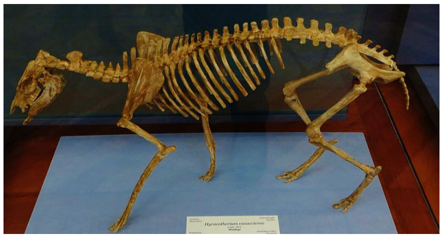

Figure 19.3. A museum skeleton of *Hyracotherium*.[7]

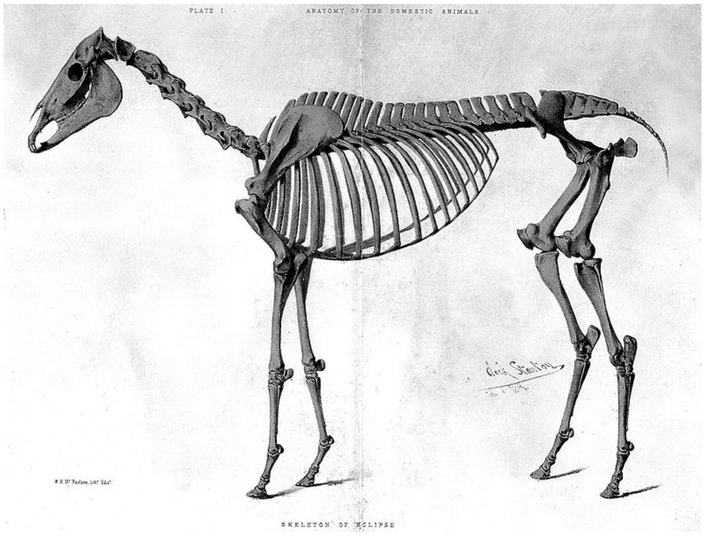

Figure 19.4. Skeleton of a modern horse. The two images are not shown at the same scale. The horse skeleton is, in reality, several times larger than the ancestral skeleton.[8]

Experiment concluded?

As it happens, a year or so after I first wrote the preceding section, I discovered that philosopher Daniel Dennett had already pursued the same thought experiment — and had received an answer. He pictured aliens visiting earth and tampering with natural selection for a while, then departing. He asked: “Would their handiwork be detectable by any imaginable analysis by biologists today?”

Dennett did the sensible thing: he consulted some biologists. “All the biologists I have queried on this point have agreed with me that there are no sure marks of natural, as opposed to artificial, selection” (Dennett 1995, pp. 316-19).

This is a dramatic acknowledgment, although the real significance of it seems to have escaped Dennett. He was clearly thinking of intelligent design when writing this passage, and feared that ID advocates might seize on the idea that you can’t disprove the intervention of an external Designer in evolutionary history. So he was quick to reply that, barring discovery of a feature positively *requiring* a Designer’s intervention — a feature that natural selection without a Designer could not explain — there was no refutation of Darwinism to be had here.

If you want a measure of how thoroughly the organism has dropped out of sight in today’s evolutionary theory, Dennett’s account offers it. Apparently it did not even occur to him to ask, not about an intelligent Designer, but about organisms themselves, whose powers of directive development, physiology, and behavior, displayed right before our eyes, constitute their entire life story. The question, still ignored today, is how the organism’s living activity participates, *out of its own purposive, cognitive, and intentional nature*, in the broader intentional coherence displayed so clearly in evolving populations.

To be as unambiguous as possible: the question here is not about an external designer, but about a purposiveness inherent in populations of organisms analogous to the purposiveness we see playing through the many more or less independent cells within a developing individual body. And the question is hardly out of bounds, given biologists' apparent agreement that "there are no sure marks of natural, as opposed to artificial, selection". One wonders how it is that the idea of meaningfully directive evolution has been so scorned if in fact all biological processes we can observe are irreducibly directive, and if we have no ready means for distinguishing a non-directive evolution from a directive evolution — or even from an *artificially* directive evolution.

I have been suggesting that there is a good reason why we cannot point to a distinction between non-directive and directive evolution. Lacking an ability to conceive clearly any sort of non-directive evolution, we have no basis for comparison. It is impossible even to imagine a coherent, organic transformation that is not in fact a coherent, organic transformation. That is, it is impossible to imagine an organic transformation not subject to the guiding principles or organizing ideas belonging to the form progressively being realized. The *coherence* of the transformation could lie only in such principles or ideas; that's just what we mean by "coherence", which would have no referent if there were only inert, quality-less, meaningless things. So the only thing biologists struggling toward a clear conception of evolution are ever in fact thinking of is directive evolution, whether they have acknowledged it to themselves or not.

The wisely purposive lives of organisms — their striving for life and survival, the intricate wonders of their capacity to reproduce, their masterful ability to gather and organize a unified, workable inheritance for their offspring — these "miracles" of directive activity (in terms of which, as we saw in Chapter 16, natural selection is defined) are so thoroughly imprinted upon our experience that not even an entrenched scientific materialism can dislodge them as implicit assumptions of our evolutionary theorizing.

So it is not that we have a choice between directive and non-directive evolution. The only biological transformation we ever see or can consistently imagine, whether developmental or evolutionary, is directive transformation. In order for us to realize that evolution is directive, it is enough for us to see that the group of once living and functioning animals known as *Hyracotherium* belonged to a complex evolutionary lineage that led to today's living and functioning *Equus*. We can understand biological transformation as such — for example, its holistic and organic character — only in a way more or less analogous to how we understand the transformation of an embryonic American Pharoah into the adult American Pharoah.

Every smallest (and largest) step and every degree of the change must first be realized in the development of an individual organism. But the contributing role of the relations between organisms may show very different emphases in development and evolution. Of course, even in the case of sexually reproducing organisms, we are usually looking, in part, at individual development following upon a "vertical" inheritance associated with the merger of two conspecific lineages. But, when we try to trace the causal relations extending through the many generations of an evolutionary process, the situation may become much more complex.

We will now take a closer look at some of these relations.

It is, in the primary sense, populations that evolve, not individual organisms

The potential functional shapes of proteins are virtually infinite. So a major question in evolutionary studies has been, “How, amid this vast landscape of possibility, can more or less random mutations in DNA lead, in any reasonable amount of time, to the particular proteins useful for an organism’s current adaptive needs?” This question has been a flashpoint for debate between intelligent design advocates and conventional biologists. The debate is, to say the least, perplexing. That’s because the foundational assumption on both sides — that *natural* biological processes are inherently non-directive — is so dreadfully wrong.

The relevant fact is that *nothing* in an organism escapes being caught up in meaningful and directive processes. There is simply no available context for talk of “random” mutations. The processes of DNA maintenance, replication, damage repair, and mutational change are among the most fully characterized and the most intricately purposive and directive activities we have so far explored at the molecular level. DNA damage repair and the closely related incorporation of mutational change are, perhaps, orders of magnitude more complex than the spliceosomal activity we looked at in Chapter 8 (“The Mystery of an Unexpected Coherence”). It takes place in the same fluid environment as RNA splicing. And there is the same play of organizing *ideas* and ideal *reasons* for what goes on — living reasons of a sort that cannot be derived from concepts of physical lawfulness.

At this point — without ever addressing the decisive problem of the rational coherence of molecular activity in the cell — evolutionary theorists are quick to tell us that, although genetic mutations are in general nonrandom, they are nevertheless crucially random in one regard:

> Mutations are claimed to be random in respect to their effect on the fitness of the organism carrying them. That is, any given mutation is expected to occur with the same frequency under conditions in which this mutation confers an advantage on the organism carrying it, as under conditions in which this mutation confers no advantage or is deleterious (Graur 2008).

So then another debate arises: “Are mutations really random relative to their benefit for the organism, or are they ‘directed’?” This is where the question of purposiveness or direction in evolution is thought to come to a sharp focus. The effort to prove or disprove the existence of “directed mutations” is often pursued as if it would tell us about the directiveness of evolution.

The question about mutations in the individual organism is certainly significant and worth pursuing. But here, too, the underlying assumption of most debate makes little sense. As I pointed out in the previous chapter, if we are talking about a *telos*-realizing evolutionary process, then the question is not about a mutation’s benefit for the individual organism, but rather about its relation to whatever is being realized in the overall evolutionary process. We are not helped much in this by making assumptions about the relation between mutations and individual fitness. Rather, we must investigate how the individual organism is *caught up* in, and *participates* in, directive processes involving populations, species, and even larger groupings.

This is much the same as with individual development. We recognize the meaningful path of development, not merely by looking at what happens to an individual cell, but by picturing the coordinated activity of all the cells in the body. Any individual cell, or group of cells, may, as we saw in the introduction to Chapter 18 ("Teleology and Evolution"), be caught up in a coordinated dying-off process essential to the formation, say, of a particular organ. In this context, it is not, primarily, the welfare or fate of individual cells we are interested in, but the larger developmental transformation. Or: we are interested in the individual cell because of the way it participates in, and is informed by, that larger movement.

But the evolutionary parallel here requires some explanation.

Far from a simple, linear process

We know that individual development is marked by more or less dramatic periods of especially rapid, intense transformation. In our own development, profound changes occur around the time when the young child is taking its first steps and speaking its first words. Likewise with puberty and menopause. Then, too, there is the entire, nine-month period of human embryological development, from the zygote onward. This pre-natal phase is marked by vastly more physiological and morphological change than occurs throughout all the subsequent decades of life.

Perhaps even more dramatic are the millions of species — for example, many insects and amphibians — that undergo one or another kind of metamorphosis. A larva becomes a butterfly, a tadpole transforms into a frog. This reorganization can be both swift and virtually total. (See the description of insect metamorphosis in Chapter 17, "Evolution Writ Small".) But such times of emphatic change typically occur between extended periods of relative stasis, or slower change.

That a similar pattern often, but not always, holds in evolution was argued in 1972 by paleontologists Niles Eldredge and Stephen Jay Gould, who called the pattern "punctuated equilibrium". Since then various forms of the idea have been broadly accepted, so that another prominent paleontologist, Robert Carroll, could write of vertebrate evolution that "instead of new families, orders, and classes evolving from one another over long periods of time, most had attained their most distinctive characteristics when they first appeared in the fossil record and have retained this basic pattern for the remainder of their duration" (Carroll 1997, p. 167).

It's not just the relative suddenness of change that matters in the present context. More significant is the remarkably nonlinear character of the processes by which major evolutionary innovations occur. My colleague, the whole-organism biologist Craig Holdrege (to whom I am deeply indebted for many of the insights in this section),[9] has drawn attention to one of the central lessons emerging from paleontological work: when something dramatically new arises in the fossil record, it is typically foreshadowed by fragmentary "premonitions" (not his word) in various taxonomic groups, some of which may then go extinct. There is no smooth, continuous, single line of development leading to the new form, which may arise not only rather suddenly, but also as a novel synthesis and transformation of the earlier, scattered, premonitory gestures.

Holdrege shows this very clearly in his book chapter on the frog ("Do Frogs Come from Tadpoles?").[10] After mentioning that no frog fossils have come to light from before the Jurassic period of the Mesozoic era, he notes that "the first frog fossils have virtually the same proportions and the same skeletal morphology as today's frogs". Earlier, there were indeed rare transitional forms possessing some frog features, especially features of the head. These were "a far cry from frogs, but if you know frog morphology well, you can see hints of what is to come". He goes on to say of the paleontological record that

> the hints or foreshadowing of what will come later are not manifest in only one type of fossil, but in several. Various elements of what appears later in the new group are manifest in earlier periods, but in different lineages. Evolutionary scientists often speak in this connection of "mosaic" evolution, since various characteristics appear in different arrangements in different organisms … Even when a trove of fossils is available, such as in the horse family (Equidae), it is not the case that they line up in a neat series. Rather, there is surprising diversity in the forms that predate modern horses (Holdrege 2021, p. 249).

In some of his other work Holdrege has pointed to the same reality in the human and pre-human fossil record. Using accurate models or professional drawings of the available skulls, done to scale, he asks students to arrange them in an order showing an apparent progressive movement toward the human form. It can be an informative (if frustrating) exercise, since no definitive sequence emerges. One skull may show a seemingly more "advanced" feature than the other skulls, while at the same time showing more "primitive" ones (Holdrege 2017).

All this resonates with other facts that have been in the news these past few years — news bearing on the most recent human evolution. We have heard a good deal about cross-breeding between humans, Neanderthals, and Denisovans, and also about the prevalence of variation within populations. The genomes of a major part of the present human race contain a significant proportion of Neanderthal and/or Denisovan DNA, and these elements are thought to play significant roles in human biology.[11]

Then, too, there is the broader fact that *hybridization* between species and genera — and even between families — is now linked to rapid evolutionary change. One impressive story was reported in the journal *Science*, in an article titled "Hybrids Spawned Lake Victoria's Rich Fish Diversity". Among cichlid fish in Africa's Lake Victoria, the rate and extraordinary extent of diversification has, we're told, "baffled biologists for decades". A mere 15,000 years ago there were only a few ancestral species, whereas today — as a result of a remarkable "adaptive radiation" — 500 or so species exist. Some of them "nibble plants; others feed on invertebrates; big ones feast on other fish; lake bottom lovers consume detritus". Varying in length from a few centimeters to about 30 centimeters, they "come in an array of shapes, colors, and patterns; and dwell in different parts of the lake".

The report goes on:

> Now, researchers have evidence that ancient dallying between species from two watersheds led to very genetically diverse hybrids that could adapt in many ways to a new life in this lake. Increasing evidence has shown that hybridization, once considered detrimental, can boost a species's evolutionary potential. Suspecting that might be the case in these fish, researchers sequenced hundreds of cichlid genomes, built family trees, and

compared the genomes of fish throughout that part of Africa. They discovered that parts of cichlid genomes have been mixed and matched in different ways through time, with various descendants being repeatedly separated and reunited as lakes and rivers dry up and refill. These hybrids had extensive genetic diversity that fueled rapid speciation (Pennisi 2018).

Figure 19.5. A cichlid fish (*Pundamilia [Haplochromis] nyererei*), one of hundreds of cichlid species in the lake region of eastern Africa.[12]

This brings to mind the claim of Mae-Wan Ho and Peter Saunders in 1979 that the isolation of a population — isolation that is commonly thought to figure in evolutionary change — "considerably reduces the role of natural selection. In fact, one cannot but notice that the really conspicuous factor in all cases of rapid evolutionary change is the relaxation of natural selection. Could it be that the rapidity of changes observed is due as much to the lack of competition as to 'genetic revolution'? A review of the fossil history shows that the decisive evolutionary steps involving the sudden appearances of major classes of organisms invariably occurred in isolation, or when ecological niches were relatively empty … that is, when competition was minimum".[13]

What strikes me in the ideas of hybridization and isolation is the fact that both point to a certain "open-endedness" and world of possibility lying before the populations about to evolve quickly. The open-endedness is genetic in the case of hybridization, where there are presumably many different pathways open to the organism for bringing its inherited genomes into harmony. And it is ecological in the case of populations entering a largely unoccupied niche — that is, without a lot of competition lying in wait along the possible paths of self-transformation.

As for the idea of a "relaxation of selection", I'm not sure there's more to notice here than the fact that natural selection never was much of an explanation of evolution. It gives us, rather, as I pointed out in Chapter 16 ("Let's Not Begin With Natural Selection"), a description of "the pattern of the natural history of life" (Langer), sketched in terms of a mere tabulation of all the extant (surviving) organisms. That is, it points us to whatever the patterns are that need explaining, and is not itself an explanation, if only because a list of survivors doesn't tell us what the survivors were *doing* transformatively along their evolutionary trajectories. Perhaps the survivors would have told us more if biologists had not been so single-mindedly focused on what *happens to them* in the way of physical (molecular) accidents.

Even more radical than hybridization has been the dramatic, *endosymbiotic* origin of different life forms at the cellular level. This has yielded some of the most decisive evolutionary transitions of all time. For example, the presence of chloroplasts (in plant cells), mitochondria (in animal cells), and perhaps a number of other cellular organelles — including possibly the eukaryotic cell nucleus — are now thought to have resulted from the merger of very different life forms. That is, a once free-living, single-celled organism becomes permanently internalized as a functioning part of a different (host) single-celled organism.

It took a long time for biologists to accept theories of endosymbiosis, which were first put forward more than a hundred years ago. This is hardly surprising because of the seemingly insuperable nature of the problem: once joined together, the two cells, with their entirely different life cycles, would have had to “figure out” how to proceed harmoniously through all the necessary and diverse functions of the new, united entity, including cell division. So it seemed that a successful merger of two very different organisms would have required an almost unthinkable and well-directed sort of “management” by both the host organism, and the internalized one. But the truth appears to be that, at critical moments in evolutionary history, such powers were indeed exercised.

Still further, we should not forget the broad fact of *horizontal gene transfer* — that is, the movement of genetic material laterally between different kinds of organisms rather than vertically through inheritance from biological parents. This movement is often mediated by bacteria or other microorganisms, and can involve the transmission of genes between widely differing organisms. This gene mixing is known to have occurred extensively, especially in simpler life forms. It, along with the other processes discussed immediately above, raises serious questions about the branching-tree model of diversifying life, based on vertical inheritance from parents to offspring, and also about the conventional idea of slow, linear, evolutionary change based on random mutations.

As if that were not enough, we have to reckon with the major role viruses have played in shaping many genomes, including those of mammals. For example, every human genome is thought to contain several times as much DNA of viral origin as the DNA of all the protein-coding genes combined.

Then again, there is the entire mass of microorganisms constituting the *microbiomes* of humans and other organisms. “The human body is a complex biological network comprising ten microbes for each human cell and 100 microbial genes for each unique human gene” (Smillie et al. 2011). It is easy to overlook that these microbes living in our gut and elsewhere belong to our bodies, and can be as functionally crucial for our lives as the cells we call “our own”. Further, they are extremely dynamic and adaptive, freely exchanging DNA and other substances among themselves.

A sprawling narrative

So you get the picture. Traditional questions about “directed mutations”, their effect upon the evolutionary “fitness” of individual organisms, and their spread through a single population via “normal” genetic inheritance — these have been rendered less relevant by our growing knowledge of actual evolutionary processes. We need to raise our sight to the larger collective sphere in which profound and relatively rapid evolutionary change can occur — the sphere where we can discover the kind of unexpected synthesis of diverse and scattered, “premonitory” features described above.

Within this larger sphere, one thing we can truthfully say about mutations (or the creation of genetic variation) is that they can be healthy for the species. They provide resilience in the face of changing environments. This is true regardless of any "fitness benefit" for the individual. And it is, of course, the species as a whole, not just the individual organism, that is evolving. But not *only* the species. There are (as we have seen) diverse interactions of various sorts among different groups of organisms, resulting in the movement of both genetic and non-genetic material between individuals, populations, species, and higher-level groups.

And so we arrive at an extraordinarily complex picture. A "strange dalliance", a few Neanderthal genes here and Denisovan genes there, the hidden and genetically seething world of microorganisms and symbionts constituting a vital part of the substance of higher organisms, the wholesale, lateral exchange of genetic resources among lower organisms (including those in our own microbiomes), the thriving of some lineages and the extinction of others that nevertheless carried for a time part of the essential "mosaic" of evolutionary potentials, and, finally, the relatively sudden convergence, or synthesis (evolutionary metamorphosis), of all those potentials in a new evolutionary configuration — well, if you want to ask about the directiveness of evolution, then all this, along with the overarching agency so clearly recognizable both in the outcome and in the only conceivable path of coordination for getting there, is the relevant stuff of your question. We are not looking at the isolated matter of a genetic mutation's fitness for an individual organism.

One thing is certain: we see no lack of room for a play of intentional, coordinating activity in evolution, just as we see a play of developmental intention through all the cells of, say, a mammal's body. And in both cases it is the *living results* of the activity, together with the necessarily coordinated, well-organized, harmonious nature of the processes for getting there — processes in which wholes, not isolated parts, must change — that tell us a directive and purposive activity has been going on.

Our current ability actually to *trace* this directive activity in evolution may be rather poor, if only because the fossil record tells us so little about the sprawling evolutionary interactions we know must have occurred. But we do know that the development of the individual horse, American Pharoah, required all the familiar, directive powers we have observed in developmental biology generally, all the intricate coordination, adaptation, and compensatory adjustment to disturbances, all the evident wisdom, thoughtfulness, and well-directed intention.

And we also know that much *more* than the wisdom of individual development was required for the evolutionary transformation of *Hyracotherium* into American Pharoah. For not only was it necessary for every ancestral animal in the relevant lineages to be capable of undergoing its own development, but so, too, the relations between mates and between predators and prey, together with all the other "complications" hinted at above, had to come under a directive, coordinating agency capable of realizing all the various metamorphoses of interacting lineages along the way.

However much we may not yet understand, we see the *fact* of this kind of directive evolutionary metamorphosis in the picture already given to us.

Where are we now?

Evolution As a Form of Collective Development

We have been led by all the preceding chapters to this present one, in which we have concluded that the question of the directiveness of evolution turns out to be almost trivially simple, with an unproblematic answer: evolutionary “development” must be directive in a manner roughly analogous to the development and life processes of an individual organism. In fact, evolution consists precisely *of* these processes, along with their directive coordination.

Their ignoring of the fundamental reality of directiveness in the life of organisms is a central reason why biologists have, for decades, denied all possibility of a coherent *telos*-realizing aspect of evolution. This emphatic denial has taken hold despite their admission that they wouldn’t know how to distinguish a directive form of evolution from a non-directive one. I have suggested that the reason for this inability is that they (at least unconsciously) know too much about living beings and therefore cannot realistically imagine a non-directive form of evolution. It’s just impossible.

But it’s obviously not impossible for biologists to convince themselves that they believe in a non-directive evolution. They can do this only by unconsciously importing into the picture the highly coordinated, end-directed biological processes they see and read about and imagine every day. The organism’s thorough-going directiveness is just too undeniable. It is fundamental to any comprehension of life. Trying to imagine evolution without it would be like trying to imagine an evolution of stones.

We have also seen in this chapter that the coordinating agency at work in evolution, while perhaps in some sense centered in individual organisms, must also play through complex interactions among many organisms and populations. We have noted a distinctly nonlinear aspect of much of evolution, where foreshadowings of changes to come (“glimpses of the future”) can be found scattered through diverse lineages, leading, at certain critical points, to a more or less dramatic and sudden reconfiguration and synthesis of much that had gone before. This reconfiguration can involve hybridization, lateral gene transfer, and symbioses, among other things, in addition to the predatorial, mating, and migratory activities that have long figured centrally in evolutionary theorizing.

All this means that the relation between a mutation and the individual fitness of an organism is no more central to the origin of species than the “fitness” of an individual cell is central to the development of a complex organism’s adult form. In fact, the death of many cells constitutes their positive contribution to the adult form. Similarly, the coordinated patterns of life and death within evolving populations can be recognized as essential to evolution.

In general, we have seen that the directive processes of evolution present us with no fundamental problems of purposiveness and agency that have not already been presented to us by the directive processes of development. Purposiveness and agency are definitive of biology, and their denial destroys biology as an independent science of life.

But while this chapter, building on the preceding ones, sets forth my core argument for acknowledging the essential directiveness of evolutionary processes, the discussion nevertheless remains incomplete. We have yet to look at the way whole organisms and whole-organism inheritances have been effectively negated or rendered invisible within current evolutionary theory. We take this up, along with questions about the role of genes, the supposed requirement for stable mutations, and the “disreputable” topic of holism, in our next chapters.

Notes

1. This may remind us of the discussion of Paul Weiss’ work in Chapter 6 (“Context: Dare We Call It Holism?”). Weiss shows how the relatively chaotic and unpredictable molecular activity within a cell is constrained at a higher level toward the order we can observe in the cell as a whole. I take Weiss’ “order” to be closely akin to what I mean here by “meaning”.

2. The nature of this “meaning” was illuminated from one angle in the example of leaf sequences” given in Chapter 12 (“Is a Qualitative Biology Possible?”).

Also, what I am saying about writing is basically true for all kinds of writing, not just writing about living processes. But it is best here not to raise too many different issues. Only consider this: writing, regardless of one’s topic, is itself a living activity, and is wholly concerned with meaning. It makes no sense to radically or absolutely distinguish between such human activity and the performances of animals — and least of all to insert a natural/unnatural dividing line between the two.

3. We could also speak of *Eohippus* or any number of other horse ancestral groups often without clear relations to each other. But I will stick with *Hyracotherium* because I am proud of having learned to pronounce its name.

4. What we call “accidents” surely can happen. But for the organism’s ongoing life, the decisive thing is how it responds or adapts to the accident. Accidents as such simply have nothing to do with the nature of life. A classic example of a significant accident was “Slijper’s two-legged goat”, who learned to walk upright on its two hind legs, with profound anatomical changes to its skeleton and musculature. Mary Jane West-Eberhard has prominently argued that this sort of plastic developmental response may have “played a role in the evolution of bipedal locomotion in vertebrates, including humans” (West-Eberhard 2005).

5. Figure 19.1 credit: Ricardalovesmonuments (CC BY-SA 4.0).

6. Figure 19.2 credit: Coolmore photo (https://coolmore.com/farms/america/stallions/american-pharoah).

7. Figure 19.3 credit: Ghedoghedo (CC BY-SA 3.0).

8. Figure 19.4 credit: Wellcome Images (CC BY 4.0).

9. I also owe a good deal of my understanding of evolution in general to the writings and lectures of Holdrege, as well as to personal conversations with him. See especially his chapters on the giraffe and the frog in *Seeing the Animal Whole — And Why It Matters* (2021).

10. Holdrege 2021, pp. 213-56. Holdrege's answer to the question, "Do frogs come from tadpoles?" is, in a very important sense, "no". The appearance of the frog represents the achievement of something new, not the mere "rolling forward" of fully determinative "mechanisms" already present in the tadpole. Upon seeing a tadpole for the first time — and even after analyzing it to our heart's content — we could not predict the existence of the forthcoming frog, as if it were a physical necessity like the movement of a planet in accord with the law of gravity.

11. I speak of DNA not only because it is the focus of evolutionists today, but also because DNA is inert (dead) enough to be recovered from some fossils in the human evolutionary lineage. It would be another thing altogether to witness how the Neanderthals or Denisovans livingly incorporated DNA into their life processes — much as we today can witness the adaptation of a single human's DNA to the requirements of a pancreas or bone, a mouth or nose. But, of course, we have no means to look back into the evolutionary record in this living way.

12. Figure 19.5 credit: Kevin Bauman (CC BY 1.0).

13. Ho and Saunders went on to say:

> There is ample evidence that the relaxation of natural selection increases phenotypic variability. Darwin (1868) first noted that domestic animals and plants were much more variable than their wild counterparts. Similarly, laboratory stocks are phenotypically more variable than wild populations (Waddington, 1957). Ford & Ford (1930) showed that wild populations themselves are much more variable during the phase of rapid expansion than when they are saturated in number, suggesting that part of the uniformity exhibited by wild populations is simply due to "stabilizing selection" (Schmalhausen, 1947), or the selection for some restricted range (usually the mean) of a phenotype (Ho and Saunders 1979).

Sources

Dennett, Daniel C. (1995). *Darwin's Dangerous Idea: Evolution and the Meanings of Life*. New York: Simon and Schuster.

Carroll, Robert L. (1997). *Patterns and Processes of Vertebrate Evolution*. Cambridge UK: Cambridge University Press.

Graur, Dan (2008). "Single-Base Mutation", Wiley Online Library, *eLS*. doi:10.1002/9780470015902.a0005093.pub2

Ho, Mae-Wan and Peter T. Saunders (1979). "Beyond Neo-Darwinism: An Epigenetic Approach to Evolution", *Journal of Theoretical Biology* vol. 78, pp. 573-91. https://www.sciencedirect.com/science/article/abs/pii/0022519379901917

Holdrege, Craig (2017). *Diversity in Human Fossil History — A Teaching Unit on Hominid Evolution*. https://www.natureinstitute.org/book/craig-holdrege/diversity-in-human-fossil-history/about

Holdrege, Craig (2021). *Seeing the Animal Whole — And Why It Matters*. Great Barrington MA: Lindisfarne.

Mayr, Ernst (1961a). “Cause and Effect in Biology”, *Science* vol. 134, no. 3489 (November 10), pp. 1501-6. Available at https://www.jstor.org/stable/1707986

Pennisi, Elizabeth (2018). “Hybrids Spawned Lake Victoria’s Rich Fish Diversity”, *Science* vol. 361, no. 6402 (August 10), p. 539. https://science.sciencemag.org/content/361/6402/539

Smillie, Chris S., Mark B. Smith, Jonathan Friedman et al. (2011). “Ecology Drives a Global Network of Gene Exchange Connecting the Human Microbiome”, *Nature* vol. 480 (December 8), pp. 241-44. doi:10.1038/nature10571

West-Eberhard (2005). “Developmental Plasticity and the Origin of Species Differences”, Chapter 5 in *Systematics and the Origin of Species: On Ernst Mayr’s 100th Anniversary*. Washington, DC: The National Academies Press. https://doi.org/10.17226/11310