I also disagree with Gould's (1985b) concept of 'emergent principles', and will argue that we need new disciplines analogous to statistical mechanics to derive 'emergent' phenomena from those occurring at lower hierarchical levels (Proposition 194).

Organicism, then, seems to have only substituted the word 'organization' for 'entelechy', leaving both unexplained, and thus was in effect a continuation of vitalism. In order to include mechanics, Driesch added what we might be tempted to call a supernatural element to everyday physics to explain morphogenesis, while to avoid Driesch's dilemma, subsequent organicist embryologists extirpated physics itself:

"Vitalism and organicism share basic questions and positions. From a negative point of view, both maintain that the study of the parts does not suffice to explain the behavior of the whole. The methods and conclusions of other sciences, particularly physics and chemistry, are held to be applicable to organisms but radically insufficient.... Biology is an autonomous science, not a postscript to physics" (Haraway, 1976).

1.05 The Grip of Vitalism

Perhaps a less genteel approach to vitalism is warranted , and it is indeed a...

"...dogmatic system, the chief actual representatives of which are the botanist Johannes Reinke [1901, 1911] and the metaphysician Hans Driesch. The vitalist writings of the latter, which are devoid of any grasp of historical development [but cf. Driesch, 1905], have gained a certain vogue through the extraordinary arrogance of their author and the obscurity of his mystic and contradictory speculations" (Haeckel, 1906). [Haeckel may have only been seeing his own faults in others: "Haeckel... was never shaken by doubt. No teaching altered his views" (Rádl, 1930). Nevertheless: "...Haeckel has undeniably contributed more than most; everything of value in his utterances has become permanent, while his blunders have been forgotten, as they deserve" Nordenskiöld, 1928.]

"Driesch and Roux differed greatly in philosophical viewpoints and technical approach, but both had studied with Ernst Haeckel. Driesch's interests were very broad, encompassing mathematics, physics and philosophy. Even as a doctoral candidate, Driesch had questioned the wisdom of his mentors; his work presented a direct challenge to August Weismann as well as to Haeckel and Roux. Eventually relations between Driesch and Haeckel deteriorated

to the point where Haeckel advised his former student to take some time off and spend it in a mental hospital" (Magner, 1994) [presumably to recover from vitalism].

"Crick (1966a) has attacked vitalism on the grounds that life is mysterious only in proportion as one is ignorant of molecular biology: 'Provided, then, that scientific study continues on a considerable scale, we can foresee a time when vitalism will not seriously be considered by educated men... To those of you who may be vitalists I would make this prophecy: what everyone believed yesterday, and you believe today, only cranks will believe tomorrow'" (Dix, 1968).

Fruton (1972), in an excellent chapter on vitalism versus mechanism titled "The Whole and Its Parts", discussed those who...

"...believed that living organisms follow special laws, different in principle from those of chemistry and physics. This view has assumed various forms during this century, and its adherents have shifted their ground in the face of biochemical advances.... [Driesch (1908a)]... developed a theory of 'dynamic teleology', with the antimechanist argument that machines cannot do what the developing embryo (or other living things) can do; this position was opposed by Wilhelm Roux and by Jacques Loeb [1912, 1916], who called attention to the ability of physicochemical systems to do what a machine cannot do. Between the two World Wars, the vitalist position was espoused by Hans Spemann, one of the two dominant figures at that time, whereas the other (Ross Harrison) stated...:

> 'This quality of 'wholeness' in the parts of the organism, particularly the embryo, has led to much speculation and even a system of philosophy. It is the capital problem of embryology to find the physical - chemical basis for it' (Harrison, 1945).

"After 1930 the philosophical ideas of Driesch and Spemann largely ceased to have currency among experimental biologists, principally owing to the successes achieved in the chemical explanation of some biological phenomena [perhaps a reference to the critical discussion of vitalism by Needham, 1931b]" (Fruton, 1972). [But cf. Abir-Am, 1991.]

As Crick (1966a) put it: "When facts come in the door, vitalism flies out of the window" (cf. Henderson, 1913). Nevertheless, the notion of vitalism lingers on as an undercurrent in modern biology, only rarely frankly acknowledged:

"The primitive association of life with movement, which we still retain, makes it a continual source of wonder that cell movements can have a simple mechanistic explanation. Certainly for myself, even after years of research on the motile tips of growing nerve axons, I still find it hard to accept that such complex, integrated, seemingly sentient structures can arise from dumb molecules. The mystery is doubtless of my own making, a form of closet vitalism, but it was the mainspring for writing this book" (Bray, 1992).

"...Despite the oft-reported deaths of vitalism and mechanism the battle between these hoary foes rages yet.... See, for example, F.H.C. Crick (1966a): '...I believe the motivation of many of the people who have entered molecular biology from physics and chemistry has been their desire to *disprove* vitalism.'" (Ravin, 1977).

Even a life well spent in reductionism leaves what might be called a lingering hope for something philosophically special that distinguishes life from the 'inanimate' universe:

"Every biologist has at some time asked 'What is life?' and none has ever given a satisfactory answer.... Though I do not know what life is, I have no doubt as to whether my dog is alive or dead.... Life appears to be a revolt against the rules of Nature.... Life is a paradox. It is easy to understand why man has always divided his world into 'animate' and 'inanimate,' *anima* meaning a soul.... When we have broken down living systems to molecules and analyzed their behavior we may kid ourselves into believing that we know what life is, forgetting that molecules have no life at all.

"My own scientific career was a descent from higher to lower dimension, led by the desire to understand life. I went from animals to cells, from cells to bacteria, from bacteria to molecules, from molecules to electrons. The story had its irony, for molecules and electrons have no life at all. On my way life ran out between my fingers. The present book is the result of my effort to find my way back again, climbing up the same ladder I so laboriously descended" (Szent-Györgyi, 1972a).

Goldschmidt (1940) summarized the situation succinctly:

"We must confess frankly that this power of regulation [in embryos] is not yet completely understood. Otherwise it would not be the favorite haunt of vitalism and its disguised variants" (Goldschmidt, 1940).

For a considerable period, vitalism seemed to spill over into the post-Darwinian theory of evolution:

"The Cornell historian of biology William B. Provine (Provine, 1987, 1988) has pointed out that in the 1920s many, probably most, evolutionists were religious. At that time Darwinian evolution theory was in eclipse, having been temporarily replaced by the hypothesis of a purposive force which was evolving life toward more complexity. The dean of the American evolutionists, Henry Osborn [1895, 1896, 1917, 1929, 1931], head of the American Museum of Natural History, called this force 'aristogenesis'; the French philosopher Henri Bergson [1907, 1911] called it *élan vital;* the French evolutionist Pierre Teilhard de Chardin [1965] called it 'radial energy.' The terms were different but the evolutionary mechanism was the same: there was a nonphysical cosmic force guiding evolution. The existence of such a force was the consensus belief (Mayr, 1980) of evolutionists in the 1920s, and it was a small step to identify the force with God" (Tipler, 1994).

However, as we shall see with the early vitalists (Lenoir, 1982; Section 1.06), the line of thought of at least some of these people may have had considerable intellectual integrity. The following hardly smacks of "a nonphysical cosmic force":

"It is best frankly to acknowledge that the chief causes of the orderly evolution of the germ are still entirely unknown, and that our search must take an entirely fresh start.... Some kind of relation exists between the actions, reaction, and interactions of the germ, of the organism, and of the environment. Moreover, this opinion is probably capable of experimental proof or disproof" (Osborn, 1917).

The problem with the predecessors to the Modern Synthesis in evolution may have been that the Modern Synthesis purported to make irrelevant a search for the cause of directional evolution. But even here, one of the formulators of the Modern Synthesis expressed support of de Chardin's (1965) efforts (cf. Dennett, 1995):

"...He has helped us to define more adequately both our own nature, the general evolutionary process, and our place and role in it. Thus clarified, the evolution of life becomes a comprehensible phenomenon. It is an anti-entropic process, running counter to the second law of thermodynamics with its degradation of energy and its tendency to uniformity. With

the aid of the sun's energy, biological evolution marches uphill, producing increased variety and higher degrees of organisation" (Huxley, 1965).

One could make fine distinctions between directional evolution and progressive evolution, and I will show in Chapters 6 and 10 how differentiation trees make at least the latter plausible in the sense expressed by Huxley (1965), and may even justify some short term directionality.

1.06 The Rise and Fall of Physics in Embryology

"Though we still know little of the 'growth energy' or the energy of life, though we are still ignorant how far it is precisely comparable (for example) with electrical energy, we can at least admit that the actual mechanical energy accompanying life obeys physical laws just as surely as its material substance obeys chemical laws" (Cook, 1914).

"...It must not be lost sight of that we still know practically nothing of the actual changes involved in differentiation. Genetics by itself will not solve this problem. To accomplish this will require all the ingenuity of the embryologist, using the most refined methods of physics, chemistry and general physiology, not only those of the present but many others still to be invented" (Harrison, 1937).

"Physics envy has long been the curse of biology" (Burian, 1988).

The relationship between physics and biology is far from settled. The conflicting points of view of vitalism and mechanism, which as we have seen persist to this day, have their roots in the early nineteenth century, when they seemed to be one and the same:

"The present study treats a period in the history of the life sciences when the imputation of purposiveness to biological organization was not regarded as an embarrassment but rather an accepted fact,... showing that a consistent, workable program of research was elaborated by a well-connected group of German biologists and that it was based squarely on the unification of teleological and mechanistic models of explanation.... It is usually assumed that the proponents of teleology are vitalists. My study attempts to show that in the early nineteenth century the central issue was not vitalism as such, but rather the more interesting problem of causality in biology.... The issue that motivated them to adopt and tenaciously defend teleological thinking in the life sciences was not religion; it was, I hope to show, a concern