development, upon which I had been working since 1891, combined with a logical analysis of the concepts of 'regulation' and 'action,' brought about an entire change of my opinions and the gradual elaboration of a complete system of Vitalism....

"Analytic experimental embryology - Entwicklungsmechanik, as Roux has called it [cf. Maienschein, 1991b] - has been able to show that there are many kinds of embryonic organs or even animals which, if by an operation deprived of part of their cells, behave in the following way: of whatever material you deprive these organs or animals, the remainder, unless it is very small, will always develop in the normal manner, though, so to speak, in miniature. That is to say: there will develop out of the part of the embryonic organ or animal left by the operation, as might be expected, not a part of the organisation *but the whole*, only on a smaller scale. I have proposed the name of *harmonious-equipotential systems* for organs or animals of this type; they are 'equipotential,' because all their elements (cells) quite evidently must possess the same morphogenetic 'potency,' otherwise the experimental result would be impossible; and their elements work 'harmoniously' together in each single experimental case....

"...Take from the blastula of a sea-urchin whatever you like (but not more than three-quarters) and the rest will always develop into a very small *but complete* 'Pluteus.'

"...Experiments now show that any part of the system, however large and wherever taken, may be cut away from it without disturbing proportionate development. This proves that a 'machine' cannot be the basis of harmonious-equipotential differentiation: for a 'machine,' *i.e.* a specific arrangement of physico-chemical things and agents, *does not remain itself, if you take from it whatever you please....*

"The harmonious system, then, is not a 'machine'; it is, in fact, as it seemed from the beginning, a something that is governed by Individualising Causality. 'Entelechy,' as a non-mechanical agent of nature, is at work in the harmonious-equipotential system" (Driesch, 1914).

What we need to come to grips with is how to have our whole, harmonious equipotential system without invoking a mystical entelechy.

1.03 Wholeness and the Symmetry of the Early Embryo

One way of looking at wholeness is in terms of the symmetry properties of the early embryo. Wilson (1925) tried to dismiss Driesch's findings on the basis of the orientation of the first few cleavages to the stratification of the sea urchin egg, although this explanation must be viewed against the later observation that: "One blastomere from an eight-cell sea urchin is occasionally competent to form a miniature pluteus larva (Hörstadius & Wolsky, 1936; Hörstadius, 1973)" (McKinnell, 1978). Even if we accept Wilson's idea as a refutation, we are still left with what seem to be fully spherically symmetric eggs, such as mammals (Pincus, 1936) and the brown alga *Fucus* (Jaffe, 1968, 1969; Kropf, Berge & Quatrano, 1989; Kropf, Hopkins & Quatrano, 1989; Kropf, Kloareg & Quatrano, 1988; Novotny & Forman, 1974; Quatrano, 1973, 1990; Quatrano et al., 1991), to account for. Some embryos start out with what is probably cylindrical (axial) symmetry:

"The nine-banded Texas armadillo *Dasypus novemcinctus* produces four monozygous [cloned] offspring routinely.... In another species (*Dasypus hybrius*), however, the typical number of monozygous embryos produced ranges from seven to twelve, with a preponderance of eight....Analysis of this development strongly confirms the conclusion that the mammalian egg is completely labile until well after... blastocyst [formation] in the number of embryos that can be initiated....

"The production of two or three embryos from a single blastoderm is not infrequent in fish, reptiles, and birds, but the offspring are fated to an early death. In all of these, the two or more embryos developing from the single blastoderm inevitably share one and the same yolk sac. When the yolk is finally resorbed, the embryos become united at their abdominal surfaces as Siamese twins. In mammals the situation is different because the yolk sac is a small remnant, empty of yolk, and plays no part in later development.... It is evident that in the mammal - as in fish, reptiles, and birds - there is no preprogramming of the egg for a specific development of an embryo and no definitive determination; any part of the ectodermal blastocyst disk can establish an embryonic field capable of self-directed development into a typical embryo" (Karp & Berrill, 1981).

Classical physics starts with a system in a given, known configuration, and calculates how it will change over time. It would be nice if we could begin a physics of embryos with well defined initial conditions, especially the overall symmetry, but even defining these will take substantial work. To the best of my knowledge, no one has yet designed experiments that critically distinguish an initial spherical symmetry from an initial cylindrical symmetry, and tested any embryo with this distinction explicitly in mind, except perhaps the cytoplasm scrambling experiments of Evsikov, Morozova & Solomko (1990). This may be because of the generally loose use of the word 'symmetry' in biology, as contrasted with its rigorous definition in crystallography and group theory (MacGillavry, 1965; Shubnikov & Koptsik, 1974). Thus, there has been a general lack of interest in such questions as:

"How did the cylindrical shape arise in the evolution of each species and in the development of individuals? This question really asks two historical questions in two very different time scales and opens the door for mechanical thinking in the areas of paleontology and developmental biology" (Wainwright, 1988).

1.04 Wholeness through the Ruse of Organicism

"What as yet, unfortunately, we know practically nothing about, is the arrangement and nature of organising relations above the molecular level. Until we can form some conception of the nature of these relations little progress will be possible in our understanding of how they come into being, and embryology will never become an exact science until embryologists take organisation seriously. For embryos are not made like plum-puddings, by a haphazard congregation of ingredients" (Needham, 1931b).

Physical explanations of Driesch's mysterious entelechy were made early on although they did not seem to divert him from his vitalist course:

"The well-known biologist Thomas H. Morgan (1909a) reviewed Driesch's [1908a] published lectures [cf. Driesch, 1929].... Taking issue particularly with Driesch's antimechanist views in biology, he too attacked their poor experimental basis and additionally presented some disproving evidence from the field of crystallography [cf. Whitman, 1888]. Here recent tests on fluid crystals had shown that 'there do exist machines of which any part can reproduce the whole form.' Although his long familiarity not only with Driesch's works but also with Driesch himself [cf. Driesch & Morgan, 1895a,b; Allen, 1978] apparently softened the tone of his criticism, he eventually concluded that 'the attempt to treat the entelechy as something apart from and yet controlling the material basis will seem to most readers, we fear, to come perilously close to mysticism'" (Freyhofer, 1987).