current philosophical theories of function, since the etiological, dispositional, and welfare views all require that natural organs either work, or historically have worked, or have a disposition or propensity to work, in order to have a function.

For example, the mule, as a reproductive dead end, figures prominently in philosophical analyses of function, where the challenge for philosophy is thought to be explaining how mule hearts can have the function of circulating mule blood even though each mule is genealogically the first of its type, and such pumping and circulation confers no reproductive advantage. What current philosophy passes over in silence are mule gonads, which in systems analysis of mule design have the function of reproduction, even though they are universal failures.

Another noteworthy difference between the design view of function and current philosophical etiological, dispositional, and welfare views is the hierarchical relativism of the design view. In systems analysis, purposes and functions are different and not necessarily linked in a chain to any privileged hierarchical level, e.g., the gene, organism, or species, whose supposed intrinsic goals (survival and reproduction) would anchor the chain of functional ascriptions. In systems methodology, the functions and purposes at any hierarchical level (e.g., cell, tissue, or organ) come from interacting design loops looking only one level up and down the hierarchy of a nested system-of-systems, and no farther.

The design-based theory of function offers a naturalist approach to function analysis that [1] breaks the chains of necessity which currently bind functioning to working, thus offering a richer view of malfunction and failure in both natural and artificial systems, while simultaneously [2] extending scientific relativity to biological hierarchies (genes, cells, organs, etc.), and [3] eliminating the last vestiges of intrinsic teleology in biology (i.e., survival and reproduction as intrinsic goals).

5 Examples of Systems Analysis

5.1 William Harvey and the Human Heart

Harvey, an Aristotelian in the Paduan tradition, sought the unifying process in human organisms that is the essence of life. The Aristotelians of Padua in Harvey's day were in an ongoing dispute with the Galenists (principally in Paris), who denied any singular life process and diffused vitality into separate organs. Harvey undertook a long study of the cardiovascular system to discover the function and working of the heart, with a view to discovering the Aristotelian life process, and in so doing discovered the pumping function of the heart and the fact of circulation of the blood (Boorstin, 1983, Ch. 47; Butterfield, 1957, Ch. 3; Nuland, 1988, Ch. 5).

That Harvey should make two discoveries at once is natural in systems analysis, since function and purpose are related as means and end, and as systems analysis jointly addresses the two interlocking loops of design at hierarchically separate levels. Indeed, given an existing, faulty but internally consistent systems analysis

as a starting point, such as Galen's liver-centered physiology of blood, at least two changes have to be made to the existing analysis to reach a new consistent analysis, since structure, function, and process each co-produce the others.

Harvey began with a detailed examination of the musculature of the heart and the vascular walls of the arteries immediately outside the heart, to resolve the systole/diastole controversy. From the exceptional strength and stiffness of the arterial walls, Harvey concluded that the heart pushed blood out to the arteries with considerable violence, and from the manner in which the muscles were connected around the heart, Harvey concluded that they work by contracting the chambers of the heart, rather than by pulling them open, i.e., that the heart does its work during systole rather than diastole. Thus, Harvey's first step was to move from new structural observations to a new understanding of heart process (Harvey, 1628).

Taking up the systolic process, Harvey sought simultaneously to examine the heart and arteries of dying animals, whose heart action was thereby slowed, and concluded that the arterial pulse temporally followed and was caused by the violent contraction of the heart. This was in contradiction to prevailing theories of the "pulsatile faculty" of blood, rhythmic throbbing of *pneuma*, theories of vascular dilation to draw blood from the heart, etc. Harvey completed his description of the systolic process by noting that the process was uniformly directional: the atria (upper chambers of the heart) always contract just prior to the ventricles (lower chambers), implying that the direction of blood flow within the heart was always from the atria down, never from the ventricles up, and therefore always from the ventricles outward. Filling of the heart between beats was only into the atria; at the point of atria overflowing into the ventricles, a new heartbeat occurred. The ventricles were not held forcibly closed between heartbeats; the heart muscle was relaxed yet the ventricles stayed empty.

From this process observation Harvey was able to infer a need for blocking the return of blood to the relaxed ventricles from the arteries once the blood had been expelled, and this lead to discovery of the cardiac valves. Theories popular in Harvey's time involving expansion or dilation of the arteries to hold blood rendered the blocking function of the valves unnecessary, and given Galen's theories of blood moving back and forth a blocking function would have been counterproductive. Since Harvey's method went beyond plausibility to necessity, Harvey could discover a need for cardiac valve existence and function, facts that were not obvious either from examination of the valve structures themselves or from prevailing plausible theories. Harvey's discovery was rooted in going beyond plausible consistency with observations to elegant, necessary functional, explanations.

Harvey's analysis of the systolic process yielded a second, independent inference of function from the passive nature of the heart between beats. Applying the principle of sufficient reason, Harvey determined a need for something to "arouse the somnolent heart", i.e., to trigger a heartbeat. From this Harvey discovered that a function of the atria was to serve as reservoirs, measuring out the time between heartbeats by their passive filling. This inference of atrial function is truly remarkable since artificial pumps, bellows, etc. have no equivalent element. Harvey could not be projecting functional ascriptions by analogy, even though Harvey did value analogy as a source of insight.