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# The Brain and Somatic Integration: Insights Into the Standard Biological Rationale for Equating “Brain Death” With Death

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## ABSTRACT

The mainstream rationale for equating “brain death” (BD) with death is that the brain confers integrative unity upon the body, transforming it from a mere collection of organs and tissues to an “organism as a whole.” In support of this conclusion, the impressive list of the brain’s myriad integrative functions is often cited. Upon closer examination, and after operational definition of terms, however, one discovers that most integrative functions of the brain are actually not somatically integrating, and, conversely, most integrative functions of the body are not brain-mediated. With respect to organism-level vitality, the brain’s role is more modulatory than constitutive, enhancing the quality and survival potential of a presupposedly living organism. Integrative unity of a complex organism is an inherently nonlocalizable, holistic feature involving the mutual interaction among all the parts, not a top-down coordination imposed by one part upon a passive multiplicity of other parts. Loss of somatic integrative unity is not a physiologically tenable rationale for equating BD with death of the organism as a whole.

*Key words:* brain death, death, somatic integration, organism, unity

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## I. INTRODUCTION

“Brain death” (BD)<sup>1</sup> is generally regarded as one of the few relatively settled issues of contemporary bioethics (Bernat, 1994, p. 115). Such consensus, however, remains at the level of statutory law and clinical praxis, while the conceptual basis for equating a dead brain with a dead human individual

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remains as confused and controversial today as ever (Evers & Byrne, 1990; Halevy & Brody, 1993; Shewmon, 1992, 1997, 1998a, 1998b, 1999; Stapenhorst, 1996; Taylor, 1997; Tomlinson, 1990; Truog, 1997; Veatch, 1993; Youngner, 1994; Youngner et al., 1989).

The concepts of death variously proposed as instantiated by BD fall into three main categories:

1. Essentially *biological*, predicated of the “*organism as a whole*” by virtue of loss of somatic integrative unity, and *species-nonspecific* (Bernat, 1984; Bernat, 1994; Bernat et al., 1981; Gert, 1995; Korein, 1978; Lamb, 1985; President’s Commission, 1981; Swedish Committee, 1984; White et al., 1992),
2. Essentially *psychological*, predicated of the *human person* (equated with *mind*) by virtue of irreversible loss of consciousness, and *species-specific* (Cranford & Smith, 1987; Lizza, 1993; Machado, 1995; Veatch, 1993; Zaner, 1988), and
3. Essentially *sociological*, predicated of *legal persons* by virtue of cessation of societally conferred membership in the human community, and *culture-specific* (Beecher & Dorr, 1971; Dworkin, 1973; Lachs, 1988; Pernick, 1988).

The first category can justifiably be regarded as the “standard,” “official,” or “orthodox” rationale for BD. By contrast, the “loss of personhood” and “loss of social membership” rationales, despite eloquent argumentation by individual proponents, have not been formally endorsed by any large-scale medical, legal, philosophical, or religious group.

This paper focuses exclusively on the “orthodox,” biological rationale – specifically, the notion of “somatic integrative unity” or “integrated functioning of the organism as a whole” and the empirical evidence for its purported dependence on the coordinating activity of the brain. Despite its intuitive appeal and the illustriousness of proponents, this explanation for *why* death of this particular organ should be equated with death of the entire organism has achieved much less universal acceptance than that equation itself. Significantly, the integrative-unity rationale was not introduced and promoted on a large scale until as late as 1981 (with the President’s Commission report and the seminal article of Bernat and colleagues (1981)), long after the neurological reformulation of death had already become firmly established in medical and legal praxis.

Both before and after that signal year, the integrative-unity argument has been rejected (at least implicitly) by not a few experts (Beecher & Dorr, 1971; Byrne et al., 1982/83; Evans & Lum, 1986; Wolstenholme & O’Connor, 1966;

Youngner & Bartlett, 1983). Moreover, despite several decades of pedagogical effort on the part of official medicine, many health care professionals, including those involved in transplantation – to say nothing of legislators, reporters and the lay public – remain unconvinced, at least subliminally, that BD is *really* death (Shewmon, 1992; Tomlinson, 1990; Youngner, 1994; Youngner et al., 1989). In recent years doubts concerning the validity and coherence of BD orthodoxy have been raised by BD scholars with increasing frequency and intensity (Byrne & Nilges, 1993; Danish Council, 1991; Evers & Byrne, 1990; Halevy & Brody, 1993; Rodríguez del Pozo, 1993; Shewmon, 1997, 1998a, 1998b, 1999; Stapenhorst, 1996; Taylor, 1997; Truog, 1997; Veatch, 1993; Youngner, 1994).

In this historical context, it is remarkable that both the American Academy of Neurology's recent practice parameter on BD (1995) and its companion commentary (Wijdicks, 1995), which described in great detail how to diagnose that the brain is dead, devoted not a single word to explaining why this should mean that the patient is dead. Yet conceptual validity must be at least as important as diagnostic accuracy.

Despite the vast number of published studies on BD, the empirical question of whether or not a human body without brain function possesses integrative unity has never been investigated with the methodological rigor typically applied to similarly important but ethically more neutral scientific questions. (That is, beginning with careful operational definition of terms, followed by examination of the physiological properties of actual BD bodies to see whether they fulfill those definitions.) This paper is intended as a step in that direction.

## II. OPERATIONAL DEFINITION OF “INTEGRATIVE UNITY”

An adequate operational definition of “integrative unity” of an organism (synonymously, “life of the organism as a whole”), in the spirit of the orthodox rationale, should fulfill the following requirements:

1. It should be generic, applicable to all living organisms.
2. It should reflect a **fundamental thermodynamical characteristic of life as actively anti-entropic, and of death as a dynamical “point of no return,” beyond which entropy relentlessly increases (Korein, 1978; Schrödinger, 1946; Shewmon, 1992; Varela, 1979).**<sup>2</sup>

3. It should correctly classify all (traditionally understood) corpses as lacking integrative unity, beginning sometime after all possibility of resuscitation has vanished but prior to rigor mortis.
4. It should adequately distinguish a composite unity (“an organism as a whole”) from a mere collectivity (of organs, tissues or cells). **The active opposition to entropy must therefore involve mutual interaction among all the parts** – hence the adjective “integrative.” The immanence of this mutual interaction is what makes for true unity, as opposed to an artificial pseudo-unity externally imposed on some collectivity that of itself tends to increasing entropy. The “organism as a whole” is a true subject of which holistic-level properties can be legitimately predicated.<sup>3</sup>
5. It should be essentially dichotomous: **“integrative unity” is either present or absent; one cannot meaningfully speak of a “partial unity” or a “spectrum of degrees of unity”** (although to be sure, “unity” is an analogous concept with different nuances of meaning at different ontological levels).<sup>4</sup>
6. Most importantly, it must not conflate mere disability or illness with death itself. If the concept of “integrative unity” is to be taken as a *sine qua non* of life, its operational definition must be open to its being ever-so-tenuously possessed, compatible with terminal illness or even a moribund state. It cannot be taken to imply absolute self-sufficiency and independence from all human and technological assistance.
7. As a corollary of points 1 and 6 together, **consciousness is not a necessary condition for somatic integrative unity.** The notion of a live “organism as a whole” that happens to be unconscious (even if irreversibly so) is not self-contradictory, even for a type of organism normally conscious or potentially conscious. According to the orthodox BD rationale, permanent unconsciousness *per se* is considered a severe form of cognitive disability, not death.

Taking all these requirements into account, the following operational definition (criterion) for integrative unity is proposed:

CRITERION 1. “Integrative unity” is possessed by a putative organism (i.e., it really *is* an organism) *if the latter possesses at least one emergent, holistic-level property*. A property of a composite is defined as “emergent” if it derives from the mutual interaction of the parts,<sup>5</sup> and as “holistic” if it is not predicable of any part or subset of parts but only of the entire composite.

Although living organisms typically have many such properties, one is a minimally sufficient number, because if there is even one property at the level of the whole, there must *ipso facto* be a whole of which it is predicated.

It is readily seen that the proposed criterion fulfills the seven definitional requirements stated above. (1) It is species non-specific. (2) The immanence and especially the stability of the mutual interaction of parts (at least in non-moribund organisms) implies an active anti-entropic organizational principle at the level of the whole. (3) No traditional corpse could be incorrectly classified as possessing integrative unity according to this criterion. (4) It is itself almost a rewording of the required distinction between composite unity and collectivity. (5) The integrative unity so defined is indeed “all or none,” not a continuum. (6) The dichotomy at issue is *life vs. death*, not *health vs. sickness*. If a complex organism that normally possesses many emergent, holistic properties is reduced to having a few or even only one, it is surely very sick, perhaps on the verge of death; but as long as it retains at least one such property, it is still an “organism as a whole” and has not yet “dis-integrated” to a mere collection of organs, cells and tissues. (7) The criterion is independent of the issue of consciousness, but its applicability is no less universal as a result. For example, an isolated living brain, supporting retained consciousness, would have to be classified as possessing integrative unity (i.e., as being a live “organism as a whole,” although hardly a “whole organism” and in fact a severely mutilated and moribund one), precisely because the consciousness would represent at least one emergent, holistic-level property. By contrast, it is not clear that any other isolated organ would possess any properties greater than the sum of its parts; therefore, the criterion would properly distinguish live from dead patients even in the hypothetical extreme of mutilation down to single organs.<sup>6</sup>

Note that with regard to “integrative unity” Criterion 1 is both necessary and sufficient; but with regard to “organism as a whole” it is necessary but insufficient: it could apply equally well to other types of composite unity. For example, a society has emergent, holistic properties but is not a living organism (except perhaps metaphorically), as it lacks a continuous physical structure separating “inside” from “outside” (even if it might have an imaginary geographical boundary). By contrast, living organisms topologically demarcate “self” from “non-self” by a continuous, closed membrane, across which matter is exchanged bidirectionally with the environment (Varela, 1979).

In addition to this direct test for integrative unity, a second operational criterion can be formulated in terms of a comparison with some reference entity accepted axiomatically as a living organism:

CRITERION 2. Any body requiring *less* technological assistance to maintain its vital functions than some other similar body that is nevertheless a living whole must possess at least as much robustness of integrative unity and hence also be a living whole.

It is an almost self-evident corollary of the first criterion and therefore fulfills the seven definitional requirements to the same extent, with special emphasis on requirement 6, distinguishing sickness and disability from death.

In what follows, it will become clear that many BD bodies fulfill both criteria. Moreover, this will necessarily remain the case by virtue of Criterion 2 even if Criterion 1 can be improved upon in unforeseen ways, so long as the improvement still correctly classifies as alive a patient (the “reference” organism for Criterion 2) with therapeutically compensated diabetes insipidus who suffers high cervical cord transection and is pharmacologically vagotomized (e.g., with atropine to treat bradycardia). For indeed, the *somatic physiology* of such a patient can be shown to be absolutely identical to that of a BD body (Shewmon, 1999). (And if the revised Criterion 1 were to classify such a patient as *not* an “organism as a whole,” it would hardly qualify as an “improvement” over the present version!)

### III. LITANY OF INTEGRATIVE FUNCTIONS

We turn now to **the empirical question of whether the operational definition of “integrative unity” is fulfilled by a human body with a destroyed (or equivalently, for present purposes, permanently nonfunctioning) brain.** One of the most common arguments in the literature for the standard rationale of BD is a recitation of what could be called the “litany of brain-mediated integrative functions.” That the brain constitutes the “critical system” (Korein, 1978, p. 26) for the body’s unity seems to follow from both the sheer number and importance of these functions. As Bernat explained,

it is primarily the brain that is responsible for the functioning of the organism as a whole: the integration of organ and tissue subsystems by

neural and neuroendocrine control of temperature, fluids and electrolytes, nutrition, breathing, circulation, appropriate responses to danger, among others. The cardiac arrest patient with whole brain destruction is simply a preparation of unintegrated individual subsystems, since the organism as a whole has ceased functioning (1984, p. 48).

Or in the words of the Swedish Committee:

It has been established that the brain governs such mental functions as consciousness, intellectual activity, memory, emotions etc. We also know today that it is from here that autonomously regulated functions such as respiration, blood pressure control, temperature control, digestion etc. are regulated. If *all* of these *higher and lower functions of the brain* are totally and irreversibly lost, the cohesion and co-ordination without which other organs of the body cannot function is also terminated. The intrinsically vital functions provided by the heart and other organs are wholly dependent on the cohesive and regulatory functions of the brain (1984, p. 37, emphasis in original).

More recently philosopher Bernard Gert, in an updated version of his original work with Bernat and Culver (1981), also stressed the multiplicity of integrative functions mediated by the brain, highlighting temperature regulation as a particularly key example (1995).

The list of such functions is indeed very long, as implied by phrases like “among others,” “etc.,” and “such as.” Nevertheless, it does not automatically follow from their sheer number that loss of all of them equals loss of integrative unity. Rather, before any conclusion can be drawn, the residual properties of bodies lacking those functions must be examined and matched against the operational definitions. It will now be shown that the empirical evidence undermines the “litany” argument in a twofold and complementary manner: (1) most brain-mediated integrative functions are actually not *somatically integrating*, and (2) most somatically integrative functions are not, in fact, brain-mediated.

### **A. Most brain-mediated integrative functions are not somatically integrating**

In the BD literature the meaning of “integrative function” is often ambiguous. If “integration” is understood as the processing together of information from

multiple sources, then virtually all the countless functions of the brain are “integrative,” from maintenance of body temperature, to eye-hand coordination, to identification of voices, to the formulation of future plans, and so on ad infinitum. Nevertheless, the “integration” of most of these functions is endogenous within the brain; only a relatively small subset has to do with integration of the body. And regarding that subset, the question at hand is whether the integration within the brain merely “has to do with” the body’s integration or actually integrates an otherwise nonintegrated collectivity of body parts.

Viewed in this light, many, if not most, of the brain functions typically cited as exemplars are seen to be “integrative” in the sense not so much of *conferring* unity upon the body as of multimodal processing within the brain, directed toward enhancing and preserving a somatic unity *already presupposed*. To take an example from Bernat’s list quoted above, “appropriate responses to danger” certainly entail complex sensorimotor information processing; but though such intra-brain integration is hardly to be belittled, it clearly serves to maintain and protect, not to constitute, the integrative unity of the body.

Moreover, some of the other functions in the list, if understood in a brain-mediated sense, are not “somatically integrative,” and if understood in a somatically integrative sense, are not brain-mediated. Such is the case with “breathing” and “nutrition.”

If “breathing” is interpreted in the “bellows” sense – moving air in and out of the lungs – then it is indeed a brain-mediated function, grossly substituted in BD patients by a mechanical ventilator. But this is a function not only of the brain but also of the phrenic nerves, diaphragm and intercostal muscles; moreover, it is not a somatically integrative function or even a vitally necessary one (e.g., fetuses in utero and patients on cardiopulmonary bypass or extracorporeal membrane oxygenation are quite alive and somatically unified without movement of air driven by either brain or ventilator). It is merely a *condition* for somatic integration to take place under ordinary circumstances, not an essential aspect of somatic integration itself. On the other hand, if “breathing” is understood in the sense of “respiration,” which strictly speaking refers to exchange of oxygen and carbon dioxide, then its locus is twofold: (1) across the alveolar lining of the lungs, and (2) at the biochemical level of the electron transport chain in the mitochondria of every cell in the body (hence the synonym, “respiratory chain”). Such respiration is not mediated by the brain, yet it participates much more intimately in somatic integration than does movement of air through the trachea.



Similarly, if “nutrition” is understood as “eating and drinking” or even merely as “swallowing,” it is indeed a brain-mediated function, but again not a somatically integrative one. On the other hand, if “nutrition” is understood as the breakdown of food into elemental forms that are either biochemically burned for energy or assimilated into the body’s structure, that is surely an “integrative function” of the organism, but the brain has little if anything to do with it.

There is also a remarkable lack of relationship between the philosophical and diagnostic “essences” of BD. Although the standard rationale contends that the conceptually critical feature of BD (what makes it death) is loss of somatic integrative unity, the standard diagnostic criteria do not require absence of a single somatically integrative brain function; instead, they require loss of consciousness, of cranial nerve functions and of spontaneous breathing (in the bellows sense) (American Academy of Neurology, 1995; Beecher et al., 1968; Conference of Medical Royal Colleges, 1976; President’s Commission, 1981; Swedish Committee, 1984; Task Force, 1987; Working Group, 1995). Conversely, the comparatively few somatically integrative functions mediated by the brain<sup>7</sup> – such as the endocrine functions of the hypothalamic-pituitary axis, the regulation of blood pressure and temperature, etc. – are not even mentioned in any diagnostic criteria, except for the admonitions that hypothermia can confound the clinical diagnosis and must be *absent* for validity, and that *preservation* of hypothalamic-pituitary function *does not exclude* the diagnosis of BD.

This discrepancy between conceptual rationale and diagnostic criteria is highly ironic and puzzling, as though the designers of the diagnostic algorithms had no particular concern to identify the physiological state that is (supposedly) equatable with death. It should therefore not be surprising that many patients with validly diagnosed BD actually manifest one or more brain-mediated somatically integrative function (particularly hypothalamic). Thus, **most brain-mediated integrative functions are not only *not* somatically integrating, but even those that *are* are not necessarily all absent in clinical BD. Other authors have also drawn attention to this strange paradox (Halevy & Brody, 1993; Taylor, 1997; Truog, 1997; Veatch, 1993).**

A few commentators have been more strict in this regard. For example, neuropathologist Cervós-Navarro gives much greater diagnostic importance to blood-pressure regulation than do most other subscribers to the orthodox rationale (1991). In his view, marked hypotension is no mere accompaniment of acute brain destruction but a constitutive *sine qua non* of the somatic

“dis-integration” of BD – so much so that if cardiovascular stability is maintained without pharmacologic assistance, in his opinion such a body could not be considered dead and organ harvesting would be illicit (1991, p. 13).

This stance is admirably logically consistent, but ironically its very consistency undermines the whole mainstream rationale for BD, insofar as **many cases of well-documented BD do not in fact involve significant hypotension.** Reporting the effects of apnea testing on cardiac function in BD, Orliaguet and colleagues described their study population as “[t]wenty consecutive patients suspected of brain death, *hemodynamically stable*, and considered as potential organ donors” (emphasis added) (1994). The American Academy of Neurology in its diagnostic practice parameter mentioned “normal blood pressure without pharmacologic support” as explicitly “*compatible* with the diagnosis of brain death” (emphasis added) (1995). Moreover, BD patients who have been maintained on life support for extended periods of time typically recover a sufficient degree of hemodynamic stability to sustain somatic life without any special cardiovascular intervention (Shewmon, 1998b).

More ironically, Darby and colleagues stated that “[m]ost [BD organ] donors can be withdrawn successfully from catecholamine support with vigorous volume resuscitation” (1989, p. 2225), and these transplant specialists actually *require* relative cardiovascular stability as a criterion for suitability for heart donation (1989, p. 2223). Similarly, Guerriero indicated that optimal candidacy for solid organ donation includes “*stable* cardiovascular function in patients who are brain dead,” and that an “*absolute* contraindication” to donation (emphasis in original) is “profound shock, unresponsive to fluids or low doses of vasopressor” (1996, p. 838). He went on to state that “every effort should be made to keep the patient in a *hemodynamically stable condition*. Extraordinary measures are *rarely* necessary. The patient just has to be kept well hydrated with normal electrolyte balance and *vasopressors used minimally* to give the patient a chance at being an organ donor” (emphasis added) (1996, p. 839). According to Cervós’ criterion, therefore, **optimal organ donors cannot be considered dead, even though their brains are dead.** The transplanters’ medical indications and contraindications for heart donation are the diametric opposites of Cervós’ ethical indications and contraindications!

There is, to be sure, a subset of BD patients who deteriorate inexorably to cardiovascular collapse despite aggressive treatment. But the fact that they are considered poor donor candidates implies that their deterioration is more

attributable to associated multisystem (especially cardiac) damage than to brain nonfunction *per se* (cf. Shewmon (1998b)). Thus, the main reason Cervós-Navarro gives for accepting that BD instantiates loss of somatic integrative unity actually turns out to be a strong reason for rejecting it.

## **B. Most somatically integrative functions are not brain-mediated**

1. *Litany of non-brain-mediated somatically integrative functions:* A second main counter to the litany-of-integrative-functions argument is that one could cite an equally long (if not longer) list of truly somatically integrative functions *not* mediated by the brain and possessed by at least *some* BD bodies, raising the perfectly reasonable question why the one list should be given such explanatory weight and the other virtually ignored. Two such non-brain-mediated integrative functions have already been mentioned – respiration and nutrition (in the above understood sense) – but many more could be cited that fulfill Criterion 1, including:

- Homeostasis of a countless variety of mutually interacting chemicals, macromolecules and physiological parameters, through the functions especially of liver, kidneys, cardiovascular and endocrine systems, but also of other organs and tissues (e.g., intestines, bone and skin in calcium metabolism; cardiac atrial natriuretic factor affecting the renal secretion of renin, which regulates blood pressure by acting on vascular smooth muscle; etc.);
- Elimination, detoxification and recycling of cellular wastes throughout the body;
- Energy balance, involving interactions among liver, endocrine systems, muscle and fat;
- Maintenance of body temperature (albeit at a lower than normal level and with the help of blankets);
- Wound healing, capacity for which is diffuse throughout the body and which involves organism-level, teleological interaction among blood cells, capillary endothelium, soft tissues, bone marrow, vasoactive peptides, clotting and clot lysing factors (maintained by the liver, vascular endothelium and circulating leukocytes in a delicate balance of synthesis and degradation), etc.;
- Fighting of infections and foreign bodies through interactions among the immune system, lymphatics, bone marrow, and microvasculature;
- Development of a febrile response to infection (Shewmon, 1998b, Table 1);

- Cardiovascular and hormonal stress responses to unanesthetized incision for organ retrieval (Fitzgerald et al., 1995; Gramm et al., 1992; Lew & Grenvik, 1997);
- Successful gestation of a fetus in a BD woman (cf. many citations in Shewmon (1998b, Table 1));
- Sexual maturation of a BD child (cf. Shewmon (1998b, Table 1): cases “BES” and “Baby A” – evidently, these children had some residual hypothalamic function, other endocrine manifestations of which are well described in the BD literature (Arita et al., 1993); and
- Proportional growth of a BD child (cf. Shewmon (1998b, Table 1): cases “Baby A,” “Baby Z” and “TK”).

In addition to fulfilling Criterion 1, the following non-brain-mediated manifestations of integration also fulfill Criterion 2:

- Resuscitability and stabilizability following cardiac arrest (Darby et al., 1989; Lew & Grenvik, 1997), and ability to bounce back from episodes of hypotension, aspiration, sepsis and other serious systemic setbacks (Shewmon, 1998b, Table 1);
- Spontaneous improvement in general health (in cases maintained for a prolonged time), i.e., the gradual stabilizing of cardiovascular status so that initially required pressor drugs can be successfully withdrawn, the gradual return of gastrointestinal motility so that initially required parenteral fluids and nutrition can be successfully switched to the enteral route via gastrostomy, etc. (cf. many cases in Shewmon (1998b, Table 1));
- The ability to maintain fluid and electrolyte balance in the absence of diabetes insipidus, or even in its presence but with no or rare monitoring of serum electrolytes and no or rare adjustments in administered fluids and hormonal replacement therapy (cf. many cases in Shewmon (1998b, Table 1));
- The overall ability to survive with little medical intervention (although with much basic nursing care) in a nursing facility or even at home, after discharge from an intensive care unit (cf. Shewmon (1998b, Table 1): cases “BES”, Teresa Hamilton, Ronald Chamberlain, the case of Pinkus, Babies “A” and “Z,” “TK”).

This is by no means an exhaustive list. The category of biochemical homeostasis, for example, can be subdivided almost endlessly down to every particular species of chemical, enzyme, and macromolecule, for each one of

which the regulation of its synthesis, degradation and functioning involves indescribably complex interactions among multiple organs, cells and tissues. Why should all these non-brain-mediated integrative functions be selectively ignored in discussions of BD, especially when they are undeniably immanent, “emergent,” non-localized,<sup>8</sup> “anti-entropic,” and more truly somatically integrative at the level of the “organism as a whole” than those in the brain-mediated list? This is especially true of wound healing, immunologic defense of “self” against “non-self,” and proportional growth.

Concerning the gestation of a fetus by a BD woman, the rhetorical mechanistic description of her body as a “human incubator” (Glover, 1993; Hunt, 1992) does injustice to the complex, teleological, organism-level, physiological changes of pregnancy (weight gain, internal redistribution of blood flow favoring the uterus, immunologic tolerance toward the fetus, etc.), which occur despite the absence of brain function.

Note that both *circulation* and *respiration* (in the technical, biochemical sense linked with energy generation) are presupposed as means to many, if not all, of the above functions. In the sudden absence of either, the thermodynamic “point of no return” for the organism is reached within a matter of tens of minutes (excluding anomalous contexts such as ischemia-protective drugs, deep hypothermia, suspended animation, etc.). And once past that moment, the progressive increase in entropy characteristic of inanimate matter would not be therapeutically circumventable even in theory (e.g., even by artificial perfusion of the body with oxygenated blood).

Circulation is not to be equated simplistically with heartbeat, nor respiration with breathing or lung function. Heartbeat is not a *sine qua non* for mammalian life (the heart can be replaced by a machine), but circulation is; neither is pulmonary function a *sine qua non* (the lungs can also be artificially substituted), but mitochondrial respiration is. Both circulation and respiration are diffuse throughout the body, and neither is brain-mediated. Thus, in referring to the traditional criterion of death, the phrase “circulatory-respiratory” captures much better the biological essence than the old-fashioned terms “heart-lung” or “cardio-pulmonary.”

2. *Spinal cord-mediated integration*: Why are the somatically integrative functions of the rest of the central nervous system, in particular, so readily dismissed? As some advocates of “higher brain” formulations have pointed out, is it not arbitrary and capricious to draw a line at the foramen magnum and declare that all central-nervous-system integrative functions above the line are

relevant to somatic unity whereas all those below are irrelevant (Veatch, 1993; Youngner & Bartlett, 1983)? The autonomous spinal cord not only mediates intra- and inter-segmental autonomic reflexes and maintains sympathetic vascular tone (Kita et al., 1993) but even possesses plasticity for primitive forms of sensorimotor “learning” (Dietz et al., 1995; Hodgson et al., 1994).

Although the cardiovascular and humoral stress response to surgical incision for organ retrieval has been attributed by some to residual medullary function (Truog, 1997), there is no compelling reason to doubt its spinal mediation, as it has been documented in cases where inclusion of the medulla in the global brain infarction was documented by four-vessel angiography (Fitzgerald et al., 1995; Gramm et al., 1992). Moreover, similar autonomic responses occur in cervical-cord-injury patients undergoing unanesthetized surgery, even though they subjectively feel no pain below the level of injury (MacKenzie & Geisler, 1997, pp. 1123–1125). The diagnostic practice parameter of the American Academy of Neurology explicitly mentioned “sweating, blushing, tachycardia” and “sudden increases in blood pressure” as “clinical observations compatible with the diagnosis of brain death” (1995).

Likewise, the spontaneous movements that can occur in BD, such as the so-called “Lazarus sign” (Heytens et al., 1989) and ineffectual breathing-like movements (Turnbull & Rutledge, 1985), have been convincingly attributed to trans-segmental integration within the spinal cord rather than to residual brain-stem function (Turmel et al., 1991; Urasaki et al., 1992). Lew and Grenvik referred to “complex spinal reflex movements of the limbs and trunk to nociceptive stimuli, which may interfere with surgery or cause undue anxiety amongst operating room personnel” during organ retrieval, for which reason they recommended the routine use of muscle paralyzing agents (1997, p. 1371). Again, the American Academy of Neurology cited such movements as explicitly “compatible with the diagnosis of brain death” (1995). Although the movements themselves carry little import for somatic unity, they visibly parallel the spinal cord’s less obvious but more relevant *autonomic* trans-segmental integration.

Given that the cord is sometimes also damaged by the etiology of the BD (especially by hypoxia-ischemia), it stands to reason that the heterogeneity in hemodynamic stability among BD patients is partially attributable to heterogeneity in associated spinal cord involvement (a frequently overlooked possibility in clinical practice). This interpretation is reinforced by the observation that in a collection of BD cases with survivals of one week or more, those with spontaneous movements had particularly long survivals, both

features (length of survival and movements) implying relative integrity of the cord (e.g., “BES”, Yusef Camp and “TK” (Shewmon, 1998b, Table 1)). It makes no sense to blame brain-stem infarction for autonomic dysfunction that is more directly attributable to spinal cord infarction.

### C. Brain as modulator and enhancer rather than integrator

To categorize the integrative functions in the “alternate litany” as “non-brain-mediated” should not be misconstrued as implying that the brain has nothing to do with them in the intact organism. Whether directly or indirectly, to a greater or lesser extent, the brain is surely involved in all of them. For example, the subspecialty known as psychoneuroimmunology focuses on how emotional states affect the immune system via the brain. But the brain’s role here is one of modulating, fine-tuning, and enhancing an already well-functioning immune system, not of imperiously micromanaging a passive and basically incompetent immune system. The same could be said for all other somatically integrative functions: they are all the more effective when modulated by the brain, but they do not entirely vanish without the brain.

Many, if not all, of the items even in the *brain-mediated* litany are, on close inspection, also seen to be modulatory and future survival-enhancing of an already unified living organism, rather than *constitutive* of that organism’s *present* unity. This is true even of a function as somatically integrative as maintenance of temperature, for which, to be sure, the “thermostat” is located in the brain, but the “furnace” is the diffusely distributed energy metabolism. Yes, BD patients do tend to hypothermia, but not in the manner of corpses in morgues. BD bodies spontaneously generate immanent heat and maintain temperature in a life-compatible range, though a few degrees below normal, with the mere help of blankets. Blankets do nothing to raise the temperature of corpses in morgues. The internal thermostat in the hypothalamus is no more an ontological constituent of life than the external thermostat of an Antarctic explorer’s ice-station or an astronaut’s space suit; its uncompensated dysfunction in adverse environments might conceivably *lead* to death but cannot logically be *equated* with death.

By contrast, any composite unity that derives entirely from one “master part” is not a unity in the fullest, strictest sense: it is a pseudo-unity, an artifactual unity, an “accidental” rather than “substantial” unity. The best examples are probably from man-made objects, such as computers, the multiple components of which are coordinated by the central processor, or

an automobile assembly plant where all stages of automated production are controlled by some central computer.

The unity of a living organism, however, is a unity in the strict, “substantial” sense: the parts are not merely a set of entities in their own right that happen to be coordinated by some other entity external to the set; rather, they are only conceptually, not ontologically distinct, each existing not “in itself” but only virtually, as a component of a higher-level entity. Each part both contributes to and is subordinated to the transcendent unity, and the equality of ontological level of “part-hood” (as opposed to “entity” or “substance”) is not contravened by the evident multiplicity of ways of contributing to the higher unity. This unity-contributing, as distinct from unity-conferring, role is as true of the brain as it is of the little toenail, notwithstanding the fact that the brain’s contribution to the long-term maintenance of vitality is considerably more important than the toenail’s. Though much more precariously alive without brain-function than without toenail function, the body can remain alive without either (perhaps with medical assistance), precisely because its unity is truly “integrative” and therefore not intrinsically deriving from or dependent on any single part.

#### IV. THE INHERENT NON-LOCALIZABILITY OF “INTEGRATION”

Integrative unity is almost by definition diffusely present throughout a complex organism. It is somatically analogous to the notion of “distributed neural system,” that golden mean between the extremes of localizationism and mass-actionism in the history of functional neuroanatomy (Mesulam, 1990). As destruction of part of an optical hologram does not result in loss of “localized information,” destruction of part of a distributed system does not result in loss of “localized function” (in contrast with the consequences of removing part of a photograph or computer). Rather, the overall quality of the holographic image merely becomes a bit degraded, and the lesioned distributed neural system merely functions somewhat less efficiently or smoothly than before.

Analogously, each part of the body, especially the brain, contributes to the stability, robustness, and richness of the body’s vitality and unity, but no one part or even combination of parts constitutes that vitality or unity. The main functions of the heart can be accomplished by a mechanical pump and the body will be just as alive as before (although more precariously so than with a



healthy heart). Most brains cannot be artificially substituted (at least presently, and perhaps even intrinsically), but *their* irreplaceability has nothing to do with whether a brain-destroyed body possesses integrative unity. The relatively few brain functions necessary for maintaining (an already given) somatic integrative unity in the wild are indeed replaceable in both theory and present practice (intensive care units are sometimes quaintly referred to as “artificial brain stems”).

A unity that must be “imposed,” so to speak, on otherwise non-united parts by some master integrator outside the set of parts is only a pseudo-unity. Moreover, applied to the issue of BD, such a notion of “unity,” implicit in the orthodox rationale, entails an exaggerated dualism between “brain” and “body.”<sup>9</sup>

*Integration* does not necessarily require an integrator, as plants and embryos clearly demonstrate. What is of the essence of integrative unity is neither localized nor replaceable – namely the anti-entropic mutual interaction of all the cells and tissues of the body, mediated in mammals by circulating oxygenated blood. To assert this non-encephalic essence of organismal life is far from a regression to the simplistic traditional cardiopulmonary criterion or to an ancient cardiocentric notion of vitality. If anything, the idea that the non-brain body is a mere “collection of organs” in a bag of skin seems to entail a throwback to a primitive atomism that should find no place in the dynamical-systems-enlightened biology of the 1990s and twenty-first century.

## V. CONCLUSION

The integrative functions of the brain, important as they are for health and mental activity, are not strictly necessary for, much less constitute, the life of the organism as a whole. Somatic integration is not localized to any single “critical” organ but is a holistic phenomenon involving mutual interaction of all the parts. Under ordinary circumstances the brain participates intimately and importantly in this mutual interaction, but it is not a *sine qua non*; the body without brain function is surely very sick and disabled, but not dead. If BD is to be equated with death, therefore, it must be on the basis of an essentially *non-somatic, non-biological* concept of death (e.g., loss of personhood on the basis of irreversible loss of capacity for consciousness), discussion of which is

beyond the present scope. The point is simply that the orthodox, *physiological* rationale for BD is precisely *physiologically* untenable.

## NOTES

1. Together with Veatch (1993), I prefer to place the term “brain death” in quotation marks, on account of its semantic ambiguity (Shewmon, 1992). There is also considerable ambiguity and inconsistency regarding how much of the brain must be dead for the brain, as an organ, to be dead or for the patient to qualify as “brain dead” (Bernat, 1992; Byrne & Nilges, 1993; Halevy & Brody, 1993; Shewmon, 1994; Taylor, 1997; Truog, 1997). For present purposes, “BD” will be taken to mean “whatever most people understand by the term (‘brain death’) (with all the ambiguity and inconsistency that entails),” or equivalently, “a clinical neuropathological state fulfilling official diagnostic algorithms and legally equated with death in most jurisdictions (regardless of the rationale for, or validity of, that equation).”
2. In describing anti-entropy as a “characteristic” of life, I do not mean to imply that it encompasses the entire essence of life or even applies to absolutely every example of life (cf. Seifert (1997)).
3. Any “part” which promoted rather than opposed entropy, such as a neoplasm, would strictly speaking not be a part of the organism. Even a “part” which simply failed to participate in the mutual interaction, such as a devascularized, necrotic finger or an artificial joint, would not be a true part. As Bernat and colleagues so insightfully pointed out (1981), the concept “organism as a whole” is not necessarily synonymous with “whole organism.”
4. The fact that “unity” is all-or-none does not preclude degrees of robustness of integration, e.g., variation in the number of mutually interacting subsystems or in the efficacy of, or amount of redundancy in, homeostatic processes.
5. The term “emergent property” is chosen for its familiarity within the scientific community, but prescinding from its atomistic-reductionistic philosophical overtones. Let us accept, for the sake of argument, the ontological premise of the orthodox BD rationale that “wholes” larger than quarks do exist and that living organisms are in fact “wholes.”
6. The thought-experiment of a brain removed from the body in such a way that both are maintained “alive” (proposed as an analytical device in some of my earlier defenses of BD (Shewmon, 1985, 1988, 1992) as well as by others) brings us face-to-face with the philosophical question of personhood. As important as that is in the overall BD debate (what I referred to in the Introduction as the “psychological rationale”), it is not germane to the strictly empirical question raised by the “orthodox rationale” and at the biological focus of this paper: namely, whether a higher mammalian body without brain function is a sick body or a non-body. Thus, we should not be surprised or consider it a sign of invalidity for the purpose at hand, if Criterion 1 might tell us that *both* the isolated brain *and* the mechanically ventilated brainless body in the thought-experiment are living organisms, just as each piece of a bisected planarian is a living organism. We are not asking the criterion to tell us which piece, if either, is the same person as before the brain-removal, only whether each piece can be considered a living entity (an organism) as opposed to a collectivity of living entities (cells). If this question ignores the most important aspect of BD, then so does the “orthodox rationale” of BD divorced from an adequate theory of personhood.

7. That is, integrative functions that cause the body precisely *to be* a body, and not simply to react to the environment in beneficial ways; these are indeed “comparatively few” relative to the brain’s countless endogenous sensorimotor and cognitive integrative functions.
8. Even in the most apparently localized of these functions, wound healing, multiple bodily systems distant from the wound participate. Moreover, the potential or capacity for wound healing is diffuse throughout the body, and it is remarkably teleological (within limits): e.g., the molding of a bone-fracture callus is ultimately fine-tuned to accommodate the physiological stresses placed on the bone and is qualitatively altogether different from scar formation in the skin.
9. Some interesting formal parallels can be drawn between two forms of contemporary brain-“body” dualism implicit in explanations of BD and two versions of soul-body dualism from the history of philosophy. In the orthodox, biological rationale, the brain plays the role of the soul in Aristotelian-Thomistic anthropology: the vital and unifying principle (“substantial form”) of the body. In the psychological (loss-of-personhood) rationale, the brain plays the role of the soul in Platonic-Cartesian anthropology: the thinking substance, in principle dissociable from an animal body the vitality of which is essentially mechanistic. In both cases “brain” and “body” are conceived as falsely disjoined and set over against one another, as though “brain” referred to an entity in its own right and not part of the body, and as though “body” referred to the epidermis and everything contained within it except the brain. Further development of these provocative analogies could warrant a paper unto itself.

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