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Falk's radiator hypothesis

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Given that the human brain represents about 2% of body weight and consumes approximately 20% of our metabolic resources at any given moment, there would be a certain appeal to an hypothesis which recognized this and tied it into a synthesis with hominid mosaic evolution. Unfortunately, what is offered here is a large mass of indigestible speculation, and some rather remarkable transformations of fancy into reified "facts" of which Falk seems to be convinced. Examples: "Selection for the radiator of *all* emissary veins . . . appears to have released a thermal constraint that limited brain size in other hominids and pongids . . ." (Figure 5 legend). Or: "The Hadar and robust australopithecine and the gracile australopithecine through *Homo* lineage have different systems for draining blood from the cranium. In the former, an enlarged O/M sinus *has been selected for and fixed* whereas emissary foramina of robust australopithecines *occur in frequencies approximating* . . . those of apes . . . *high frequencies of emissary foramina are selected for over time.*" (emphasis added; Figure 4, legend).

There is not a shred of empirical evidence that natural selection has worked on these venous drainage patterns. One cannot test whether or not the *apparent* high frequency of the O/M drainage system in robust australopithecines was a polymorphism, one end of which could have become fixed in the O/M direction purely through *random genetic drift*. No empirical evidence exists that brain size is limited by a thermal constraint (beyond metabolism), either within, between, or among species! Increase in brain size among hominids, including between early and late "robust" forms, or between *Homo habilis* and *Homo erectus*, could be attributed to increase in body size, as there is some reasonable evidence for brain-body size correlations that are statistically significant, even within species (see Holloway 1980). Falk's scenario ignores this possible avenue.

How many times is it necessary to reiterate to physical anthropologists that a correlational analysis is not a causal analysis? Thus, there is no solid empirical evidence for any of the following:

1. a selective advantage to either drainage system in hominids, apes, living human, or even monkeys;
2. that any significant relationship exists between brain size and adaptive behavioral repertoires (read "intelligence," or "information processing," two terms often used to cover our ignorance) either within or between species of primates whatever Van Valen's (1974) musings and Falk's conjectures;
3. a causal or biologically meaningful relationship between either form of the drainage pattern and bipedal locomotion; that is, there is no evidence to indicate that some subset of bipedal locomotor variability correlates with any subset of variability in venous drainage pattern;
4. a clear separation of the ecological habitats or locomotor and behavioral adaptations between early and late robust australopithecine hominids and even earlier gracile ones, and those constituting early *Homo* (speculations abound, but evidence is simply not there);
5. that cooling of the brain during hyperthermia (caused by any behavioral patterns including bipedalism) *inadvertently*

removed a constraint that previously prevented brain enlargement;

6. that a constraint of *any kind* was against previous hominoid or earlier hominid brain enlargement;

7. an understanding of the nature of the exact interrelationships between those features of "mosaic evolution" mentioned by Falk, such as bipedalism, brain enlargement, brain-body allometry, reorganization, selection for venous drainage patterns, freeing of the hands, reduction of cortical areas devoted to toes being co-opted for the hands, language, etc. These are unknown, probably unknowable, and are presently nontestable;

8. the idea that bipedalism arose to reduce surface area receiving solar heat loads first suggested by Fialkowski is interesting. How can one ever demonstrate, however, a connection between standing upright to reduce body surface area from the fossil record? At best, Falk's speculations agree with Fialkowski's speculations.

At this level of speculation, I could easily assert that as the Pliocene progressed and aridity increased, the distances between shade trees increased and hominids developed bipedalism so that they could stand in the shade during midday more easily, thus reducing the risk of hyperthermia, inadvertently leaving the hands free to make sombreros.

But the problems with Falk's presentation here are more than simply reifying relationships that are undemonstrated. There are some serious problems with the data themselves. For example, is the Omo 338 specimen regarded as a part of the robust sample? Taung? There is no consensus on these or other specimens. Where is there any evidence for O/M drainage in any of the recently discovered early robust hominids, for example, WT 17000? The disposition of the sigmoid sinus is not support for an O/M drainage pattern missing in the originals. Given the sorry state of most fossils in the mastoid and parietal regions of the basal and dorsal cranial regions, how can one be certain one is correctly scoring emissary veins or O/M drainage patterns? In general, the older the hominid specimens geologically, the more damaged they are. Are parietal emissary veins related to brain cooling or to some other physiological function? What do differences between 25, 50, and 75% mean when the sample size for different hominid groups is less than five in many cases? Where, incidentally, is there any evidence (in light of the above) for "continued elaboration of the radiator" suggested by Falk's Figure 5? In that same paragraph (p. 15) Falk cites herself (Falk 1980a) as the source for the fact that *Homo* has three times as much brain weight as would be expected for a primate of its body size. Surely she must be aware that Passingham (1973; 1975a) showed this much earlier. This was common knowledge in the '70s (e.g., Radinsky 1978), once allometry came into vogue, and was probably appreciated in the 1960s by Jerison and Stephan, among others.

In short, whatever the proposed virtues of a "mechanistic theory," I think the radiator theory has too many leaks to be taken seriously.

Welcome light on a hot topic

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This delightful, original, and superbly documented contribution was so much fun to read and so convincing that it is almost above criticism. The basic ideas are completely acceptable, and it now seems obvious (having read Falk) that the hominid brain did not become enlarged until there had been earlier evolution