The Human Nature Review
ISSN 1476-1084
URL of this document
http://human-nature.com/nibbs/03/skoyles.html

Human Nature Review **3** (2003) 142-148

Book Review

Up from Dragons: The Evolution of Human Intelligence by John R. Skoyles and Dorian Sagan. New York, McGraw-Hill, 2002.

Reviewed by Neil Greenberg

The pre-Socratic Greek**,** Xenophanes, more a poet than a philosopher, nevertheless recognized that we lurch from one bit of confident knowledge to another. He concluded his (known) writings saying, "Here then let these opinions stand-in resemblance to the reality." [Freeman 1959] And that is what John Skoyles and Dorian Sagan have done in *Up from Dragons*, their collaborative book on the evolution of human intelligence.

Books on behavioral neurology are proliferating with our growing appetite for empirical anchors for our extraordinary flights of behavioral fancy and our perennial anxiety about what is *really* real. Unlike the other critters with whom we share the earth, we are not satisfied with "real enough to get by." We aren't wired that way. And now we are regaled with another (very) clever assemblage of opinions anchored in the newest and most fascinating "facts" available. Skoyles and Sagan review the past (as much as we are able to reconstruct it), along with the present potential, and the future possibilities of our brains and of our species. Along the way they introduce us to several key brain structures, possible mechanisms of the their orchestration, our capacities for symbolic thought and language, the origin of a sense of self, and finally where our "third millennium" brain might take us.

Skoyles and Sagan have *not* rounded up the usual suspects – at least not in the usual way. Their book is less technical than some, but palatable wherever technical details are needed. Their almost 300 pages of text (supported by about 750 notes and 1000 references) will hold your attention. New and sometimes arcane aspects of neurobiology have been woven into a great text about the substrates of our behavior (I love the fact that "text" and "textile" have the same root). My antennae went up early on by their having framed their text with the old view that human uniqueness somehow places us apart from the rest of nature. On the basis of claims about our extraordinary plasticity of brain, they imply that we have broken with our ancestors. But other species also have extraordinary neuroplasticity and some even grow new neurons on an annual basis (see for example, Gage, 2002). Still, there are significant differences in both the nature, neural substrate, and the ends that are served by *our* plasticity. "This endowment," they write, "this changeling nature, this plasticity, makes us unique among

animals." But in one sense or another, *all* species are unique. We can just reflect upon the fact.

Quibbles about the frame aside, the fabric they weave is great. They press ahead where Dorian's dad, Carl Sagan, in *The Dragons of Eden* could not yet go until neuroscience attained at least a little more maturity and technical resolution. Carl's trademark, "billions and billions of stars" are complemented now by billions and billions of neurons of the cosmos within.

It is arguably true that "No other animal species before us has traveled so much evolutionary territory in so little time." And also arguably, this phenomenon, is "one of the greatest scientific mysteries . . .[and cannot be] "answered simply, even glibly, with notions such as 'culture' or 'ideas'. . . " And it is likely that this phenomenon was in large measure, facilitated by brain evolution. The familiar but necessary truisms stated, they now boldly go where *Dragons of Eden* could not have gone before, into the spiraling coevolution of mind and society. Others have leaned in this direction (Terrence W. Deacon's excellent *The Symbolic Species* (1997) comes to mind), but Skoyles and Sagan aim to capture more. Their web is less finely woven but more inclusive.

Early on (Ch. 2) the authors take up the idea of "extrasomatic inheritance" from *The Dragons of Eden* and introduce their concept of *"mindware"*, cerebral software which shapes the future and reinterprets the past in its support. It is studied by means of "*braintech,*" their term for our new and thriving abilities to visualize the brain in action. The idea reemerges in the final chapter in which "gifted environments" are seen to be the venue that sets the limits on mindware. The authors have discovered "cognitive ergonomics." This term was once used to characterize human-computer interfaces, but it can be more broadly understood to reflect an appreciation for the importance of respecting and designing for the congenital contours of the mind. Our understanding of these contours are made progressively more accurate with each successive generation of descriptive technology. The "gifted environments" the authors propose as the key to unlocking the potential of the brain might be better understood as "empowering environments" —ones which foster specific paths of development, an opportunity sometimes limited to brief windows of developmental time.

Embedded in the frontal lobes – A. R. Luria's "organ of civilization" – is the structure the authors regard as the "brain's brain," that third of cerebral substance that we call prefrontal cortex. It is our most distinctive piece of neural machinery and 70% larger in us than in our near kin, the chimp. It is so large that it must be extraordinarily important, yet the evidence of post-lobotomy behavior suggests that we might not miss many of its functions. But on the other hand, very slight advantages can have massive consequences: competition is the essence of evolution and amongst competing individuals (and even competing pathways through the brain) success can depend on milliseconds. The prefrontal cortex is also the organ of imagination. Here is where one of the minor difficulties of the text becomes more intrusive. The *wonder* of all the things the prefrontal cortex is responsible for begs for more commentary on their likely causes, consequences, and contexts. There is a stimulating list of abilities described, but a dearth of explanation. The *wonder* of the organ of imagination. Here is where one of the minor difficulties of the text becomes more intrusive all the things the prefrontal cortex is responsible for begs for more commentary on their likely causes, consequences, and contexts. They quoted earlier in the book a perceptive comment by Paul MacLean (1990) that might be taken to heart here. MacLean observed that for a sense of "reality" (as well as of "self" and "truthfulness") the emotion-mediating limbic system must be a close collaborator with the neocortex. A few compassionate narratives about real people in the spirit of Oliver Sacks (1985) or Elkhonon

Goldberg (2001) would help Skoyles and Sagan make their points in a more penetrating way. The authors have taken the ancient dictum to heart: "If you can't explain it, describe the hell out of it." Still, their details and eloquent descriptions almost seem to merge into explanation.

The seamless writing and graceful segues creates the impression that all the bases are covered – but far from it. The prima donna, I mean prefrontal cortex, didn't get where it is all by itself. Here, a bit more credit for the supporting cast, such as the basal ganglia and thalamic nuclei, would be informative as well as gracious . Fortunately, the authors now disarm concern about the completeness of coverage with the warning near the beginning of the next chapter. They confess in their way to what Xenophanes was so wary about – that our apparent confidence is based on fragments of knowledge and that all the rest is only plausible extrapolation. "Like military intelligence," they say, "we have to go on the fragments that are available." Even here the logic of the lamppost prevails: we search for facts where we have light, and pretend that the facts that lay in darkness do not exist. Fortunately our authors do not often fall victim to this common fallacy. They do not grope in the darkness but they do venture into areas where the illumination is at present dim at best. For example, electronic oscillations – a fine candidate for coordinating neural processes centered in far removed parts of the brain –the trick, as they call it, "that lets [us] process things across the brain as if they were all being processed in the same place" (p60).

Subsequent chapters deal with neural networks and what has "nourished" their dramatic growth; again annoyingly framed by an evolutionary oversimplification: the idea that neural plasticity somehow empowers the brain "to do more than it had evolved to do" (p70). It seems to me that most traits have evolved from something else and that the capacity to manifest neural plasticity is in itself an evolved trait that has empowered the brain to do more than it had done but which has been barely exercised. Still, the authors develop their subsequent ideas nicely and provide welcome emphasis (and an antidote to the "going beyond evolved capacity" idea) on the idea that the prefrontal cortex is developmentally delayed and is required to complete its development in the richer world *outside* the womb. Only here can the specifics of the environment can be registered in ways that the extreme conservatism of the womb does not allow. The next chapter on Machiavellian neurons is a review of the forces that influence primate sociality, but once gain, a shortage of taxonomic breadth diminishes the richness of the concepts: relatives starting "helping each other" long before primate or even mammalian sociality emerged. In this chapter, the neglected theme of neuroendocrine influences emerges timidly, but is welcome nonetheless. Also, it was good to see play behavior well represented, although the evolutionary perspective on play as developed by researchers such as Gordon Burghardt (e.g., 1999) might have been useful.

A model of sorts that threads through the volume is a "formula" that represents the forces at play in the making of a mind: NeuroPlasticity (NP) + Prefrontal Cortex (PC) + Fission-Fusion (FF) = human mind. Before they are done, Skoyles and Sagan will add "symbols" and "time" to the formula. While developmental flexibility and the part of the brain most prominently associated with impulse control and foresight are predictable parts of a formula for mind, the author's addition of the anthropological idea of fission-fusion is more interesting. Here, the capacity of social primates to break into small groups (fission) while maintaining large group integrity (fusion) is viewed as one of the driving forces in the development of communication skills and the attendant cognitive capabilities. Interestingly, the authors had previously mentioned (in different terms) the fission and fusion of neural control centers in connection with motor control of separate ver-

sus fused fingers. Such functional demand-driven neuroplasticity would be entertaining to explore in the social context as well.

A discussion of sociality's dark side (the famous Milgram experiments showing people obey orders despite ethical misgivings) launches an inquiry into the nature of human freedom and individuality. Each of us is a bird in a neurochemical cage, learning to live and prosper as best we can in a social world that has been internalized in our head — "the troop within," the authors call it. Before long however, we are introduced to the site of our respective "me-ness" in the anterior cingulate. Working through the "self's" need for memory (thinly discussed) and frames of reference associated with the hippocampus of the brain, the authors deliver us to the threshold of *consciousness*. This is the chapter the authors say they would rather not write – but they have been writing it all along – at least in so far as they have conveyed the idea that a sense of wholeness can emerge from a coordinated aggregate of multiple functional modules. Examples they used include the sense of vision, which utilizes 32 different areas of the brain, and the sensations of one's own body, which is the aggregate effect of seven different neural maps. Gamma oscillations, first identified several chapters back, are at the moment the best candidate for a "binding" mechanism, creating an apparent unity from the multitude of specialized modules of sensation and action. The authors confess, however, that it may as likely be a correlate of consciousness as its substance. The prefrontal cortex emerges again as an organ of freedom as well as imagination – in particular freedom from the constraints of reality and its contents. Here the authors sniff an interesting new direction – the potential importance of stress biology in driving the brain's evolution, but do not quite sniff it out as (for example) Huether (1996) has tried. The urge for independence as driven by the prefrontal cortex goes even further, however, alerting us to the inevitability of death and engendering a desire to escape the physicality of the world that is so irresistible that we often presume an alternative we can never know and want desperately to believe in, creating the body-spirit dichotomy.

An evolutionary point of no return (actually they are almost all points of no return, at least not to the original condition) was a prefrontal-cortex-enabled shift in behavior presumably made by our primate ancestors (as now represented by chimpanzees) that allowed social attachment without physical proximity. In other words, the "other" could be held in mind without the need for immediate tactile or chemosensory reminders. The mechanisms of bonding and powers of symbolism were neatly explored in two chapters. The limitations of smell as an agent of bonding compared to sound or image (that may be remembered in a different way) begged for an fuller exploration, considering significant differences in the relative antiquity of their corresponding brain areas, but was satisfying nonetheless.

The crucial importance of "gifted environments" in evoking the potential locked in the primate (or any) brain was explored with Lucy and Kanzi, the *Australopithecus* unearthed in the 1970s and the "talking" bonobo chimpanzee born in 1980. Here the authors miss a sterling opportunity to develop the evolutionary significance of the often underestimated idea of "sensory bias" and "sensory exploitation." These ideas build on the belief that many traits can exploit a sensitivity for a specific stimulus that had previously evolved in a different adaptive context (for example, Ryan et al 1990). The authors hint at this when considering the many collateral advantages of buying a car for one specific reason and find that it is available for other less urgent functions as well. The last decade of literature is full of ideas related to this that could enrich our understanding of how the prefrontal cortex, as a utilitarian organ, seems so especially constructed to find countless new ways of applying itself, some of which may exceed by far the original advantage pro-

vided.

What could be responsible for the incredible evolutionary sprint that brought our species to its present exalted but precarious position? Skoyles and Sagan deal with our "runaway species" in a chapter that introduces us to sexual selection. This was Darwin's answer to the apparent burdens of extravagant displays –the peacock's tail problem. But this idea extends beyond obvious morphological traits that signal a male's underlying competence to provide superior offspring. When there is time enough to make more than a reflex response, cognitive mechanisms can come in to play. And when those mechanisms are part of a positive feedback loop (in which more expression of the trait makes the bearer more attractive, leading to preferential mating and even more expression), extremes (some of which we manifest) are inevitable. With the springboard of social development, sexual selection has become *sociosexual* selection. The authors might have paraphrased the conservative American politician Barry Goldwater's signature line, "Extremism in the defense of suitable mates is no vice, moderation in the pursuit of fitness is no virtue." But here is just where some understanding of cost/benefit analysis might be helpful – especially in understanding which aspects of the environment permit the trend to develop and which rein them in.

Excesses of expression can apparently create their own selection pressures and take on a life of their own, unrelated to the forces that gave rise to them. Ritualization, as the ethologist Desmond Morris (1966) explains it, involves the gradual transformation of non-communicative traits into signals (for example a thermoregulatory feather-fluffing reflex could become a feather-display, such as that of the peacock), some signals have become "emancipated" from the reflex that gave rise to them and now exist *only* to communicate. How is the control of a behavioral pattern shifted from the stimulus that evokes a reflex to one which triggers a social signal? Morris also provides a handy list of the many ways that units of behavior have become transformed. His list has been derived from extensive experience with many species and often the items he identifies are not obvious until pointed out – such a comparative perspective would, in concert with Skoyles and Sagan's experience and insights, have been immensely useful.

The authors help us envision good reasons why certain traits might become excessively represented, but they also inform us that there is no clear need for such excesses in the cerebrum as evidenced by well-functioning humans who sometimes have brains smaller than Nariokotome boy, a young *Homo erectus* found in 1984. As Skoyles and Sagan point out, we seem to have more brains than we need – and there is a cost: the cranium that contains this hypertrophied organ necessitates a dangerously difficult birth. Further, the relatively premature infant requires costly investments of time and energy.

The authors develop their concept of "mindware" in a chapter on "the symbolic brain." We do not get an unambiguous definition of mindware but we learn that "symbols make mindware possible." It was the fission-fusion lifestyle of apes that built on the capacity to symbolize that helped apes thrive. These neurological competencies were not only reconfigured by the amazingly plastic prefrontal cortex, but their influence could ramify throughout the brain to affect the workings of other structures. Analogous to computer software and a little like the unit of behavior Richard Dawkins termed "memes," mindware also incorporates what Carl Sagan termed "extrasomatic language," first ventured 25 years ago in "Dragons of Eden". The resemblance to (if not identity with) "culture" needs to be explored.

Tools such as hammers or and computer keyboards do not change the anatomy of our hands very much if at all, but the use of symbols can change the brain in conspicuous ways, especially in the young. But so can simply observing others around us: "mind upgrades"

may be available for the watching. That is, a special population of "mirror neurons" in the motor cortex of an observer's brain is activated by the sight of actions in a "teacher," intentional or not. Between this proclivity and the teacher's gift for focusing the student's attention, imitative dispositions can be transmuted into complex skills, such as writing books. And all of this with a brain that was used to compensate for our frailty when, as Skoyles and Sagan believe, we were in direct competition with the bigger, stronger, Neanderthals! Making a virtue of adversity (my favorite candidate for another general principle in evolution) we began to capitalize on minor cerebral gifts and never stopped. Indeed, the authors explain, the specifics of certain ways symbols are used (the Greek language in particular) may be responsible for our competence (such as it is) in abstract thought.

In short, *Up from Dragons* is a valuable and entertaining addition to the literature, It is crammed with innovative interpretations gingerly ventured. It has wit and charm: many tiny asides such as the color of gray matters when it is alive (pink); or "the Saber toothed sausage" (the blind mole rat) provide just the right pitch, and are welcome spice in the stew. The authors are great at weaving plausible hypotheses from "provocative suggestions" gleaned from the literature, but they are usually wary of over interpreting their "meaning." Abundant references and notes show a scholar's attention to detail in lockstep with a true teacher's desire to inspire and fire the imaginations of students. I would expect some extraordinary careers to be launched by this book – chapters such as "Neurons Unlimited" will be recommended as a supplementary reading for my physiology-wary ethology students. The hero of the book is the prefrontal cortex, and it provides a fine springboard and perspective from which to view other taxa and consider their relative success without such "advantages."

Despite several disappointments (especially sketchy coverage of the comparative background to some ideas and glibly stated evolutionary concepts) but I in no way want to mitigate your enthusiasm for reading it. The book is the right size and pitch for the educated public and sufficiently broad that even specialists will find collateral information rewarding. The authors caution readers about the fragmentary nature of what we can be confident about, but a couple of fragments from other perspectives should at least be given a nod. For example, the interdisciplinary field that has come to be called "psychoneuroendocrinology" is neglected. Also, some comments about developmental forces such as sensitive periods and even behavior genetics would be helpful. Ernst Mayr's old (1988) idea about "open" and "closed" genetic "programs" (those more or less susceptible to environmental influences, respectively) would likely help some people more fully sense the epigenetic interplay of forces at work. The subtle influences of the environments of development could be more explicitly outlined, and powerful internal forces such as subclinical as well as manifestly dysfunctional stress responses could be pointed out. Perhaps these could help the authors more fully reconcile the seemingly conflicting themes of the great flexibility and our extreme sensitivity of our brains. The book is rich with innovative ideas and threads which, are intrinsically entertaining but also if followed could lead to a fuller understanding of who we are – cumulatively as well as individually– and who we could become.

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