The 20 W sleep-walkers

Ladislav Kováč

The energy output of the resting adult human body is equal to the power of a 100W electrical light bulb. With a hard physical load, it could be up to seven times larger. All humans on Earth warm up the universe by 650 GJ of thermal energy every second by their mere existence—although, by virtue of technology, humankind's total energy output is actually 25 times larger. Each living cell contains millions of molecular machines. Other than macroscopic machines, these tiny machines constantly jiggle owing to the Brownian motion, so they frequently break down and must be continually repaired and restored. The basal energy demand is used for maintenance, repair and renewal.

Remarkably, the brain alone consumes 20% of the body's chemical energy, even though it accounts for only 2% of the body's mass. Metaphorically speaking, we all have a 20W light bulb burning in our head, even when we lie still in complete darkness doing physically nothing. The human brain, with the dominating neocortex perched on top of the older strata of our central nervous system, is the supreme example of life's tinkering, "a sort of installation of a jet engine on an ancient horse cart" (Jacob, 1977). The brain uses chemical energy to create and maintain patterns of chemicals and synaptic connections. These patterns, which appear at the material level as ordered, complex chemical states, and which, at the mental level, represent emotions, thoughts and consciousness, are tautological translations of material processes into mental phenomena.

Accordingly, one might expect that mental exercise, such as solving a complex mathematical problem, would increase the energy demand of the brain. Yet, the brain as a whole shows no difference in the energy budget between 'resting' and

'busy' states—an observation that has long puzzled scientists. This puzzle was eventually solved when new imaging techniques allowed local energy fluxes in specific brain areas to be measured: when some areas of the brain work intensively, the energy flux in other areas decreases (Raichle *et al*, 2001).

The brain seems to be constantly working at maximum power, even if it receives no signals from the environment. It is akin to a car with the engine always running at full speed, whether the car itself is moving or not (Kováč, 2008). The brain guzzles up—per unit weight—as much energy as the heart muscle, about 16 times more energy than the skeletal muscle at rest, or as much as the leg muscles during a marathon race. The bloodstream copiously supplies it with fuel and oxygen, but it also functions as a coolant: the high power of the brain needs efficient cooling.

When the brain receives no signals from the environment, a considerable part of its energy is used in daydreaming: the human mind may be spending as much as half of its wakeful time daydreaming (Klinger, 1990). This comprises not only the creation of fanciful stories similar to those we dream during the night, but also the rehashing of all possible and impossible alternatives of the past, present and future activities. This interior universe of daydreaming creates a continuous series of fictional rewards and punishments, which steadily builds up the unique and idiosyncratic personality of every human individual by conditioning. This may explain our capability to work for years on our career, tenaciously, with self-restraint and self-denial, as if we were motivated by the mirage of an ultimate reward. Apparently, it is not the latter in the remote future, but our present fancies of it that provide immediate, positive rewards and function to reinforce our deeds.

Each of us is an 'inner human being', largely set up by self-reinforcement. Such a being has been categorically refuted by Burghus Skinner, because he was convinced that humans, just as other animals, can be formed by reinforcement through rewards and punishments coming from a single source: the external natural and social environment (Skinner, 1972). Yet, the inner environment seems to be no less important than the external one. We live in a dual world. We move and act in this world as somnambulist rope walkers, lured by the spell of the full moon of our personal desires and dreams.

Physically, the brain is a macroscopic machine made of 100 billion neurons. The computer model of the brain appears mistaken, even as a metaphor. The brain is a hypercomplex network of a myriad of tiny electromotors, immersed in a complicated solution of chemicals—this would be a more appropriate metaphor of the brain. It is the organ by which we experience the world—that is, we feel pain and pleasure, we yearn, and in order to find out how to minimize pain and maximize pleasure, we think.

REFERENCES

- Jacob F (1977) Evolution and tinkering. *Science* **196**: 1161–1167
Klinger E (1990) *Daydreaming*. Los Angeles, CA, USA: Tarcher
Kováč L (2008) Bioenergetics—a key to brain and mind. *Commun Integr Biol* **1**: 114–122
Raichle ME, MacLeod AM, Snyder AZ, Powers WJ, Gusnard DA, Shulman GL (2001) A default mode of brain function. *Proc Natl Acad Sci USA* **98**: 676–682
Skinner BE (1972) *Beyond Freedom and Dignity*. London, UK: Jonathan Cape

Ladislav Kováč is a cognitive biologist at Comenius University, Bratislava, Slovakia. E-mail: kovacl@fns.uniba.sk

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