Exploitation of an unconscious veto mechanism, mediated by a specific cortical circuit, and made possible by an adequate very-short-term memory span, paradoxically requires conscious awareness. Part of the same circuit, interacting with other brain components, permits internal simulations of the body's interactions with the environment, thereby providing the basis of mind.

KEYWORDS: Consciousness, veto mechanism, muscular movements, body/mind problem.

It was recently suggested that the evolutionary advantage of consciousness lies in the power of choice it gives an animal (Cotterill, 1995). But neural networks of the feedforward type also choose (North, 1987), as when they unconsciously discriminate between the letters T and C (Rumelhart et al., 1986). How does choice in conscious animals differ from this neural-network variety?

A feedforward network's choice incorporates non-biological features; it is helped by grandmotherization of its input and output neurons, these being given discriminative abilities (Crick, 1989). And such networks do not have to choose between temporally-extended events, which are characteristic of animal behaviour; grandmotherizing a sequence of neural signals is not an easy task. Finally, feedforward networks are merely fed with information, and their outputs are read off by intelligent agencies; they usually do not acquire experience of their own volition. Animals do (Clark, 1997); the environment is just as much a black box as is the brain of the creature exploring it (Cotterill, 1995).

Conscious animal choice is well illustrated by navigation. One dictionary definition of this word is 'methods of determining a ship's position and course by the principles of geometry and nautical astronomy'. These are used by a navigator. The other meaning, more suitable for the person in charge, is commonly applied to explorers of bygone days; it refers to

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R.M.J. Cotterill, Biophysics, Building 307, Danish Technical University, DK-2800 Lyngby, Denmark. E-mail: firocot@gbdt.dtu.dk
navigation in the general sense. Conscious animals are such navigators, probing their environments through (sequential) muscular movements, including (in advanced creatures) those of the vocal apparatus.

It was postulated (Cotterill, 1995) that acquisition of information is always an active process, even when merely the upshot of thought. Such accumulation is not necessarily conscious, however. For example, each walking stride is effectively a question: *is the ground still there?* Only when we encounter an irregularity, a hole perhaps, do our motor explorations suddenly become conscious.

Active information procurement inevitably takes time. Signals must pass to muscles, and reafferent signals must return via relevant sensory modalities. Proprioceptive information must simultaneously return from muscles, related joints and body surfaces. Libet *et al.* (1979) showed that about 500 ms elapses before we become conscious of an event, so Carpenter (1996) is right in suggesting that consciousness makes us observing bystanders, because we are informed too late of our actions.

Libet (1989) discovered a veto mechanism requiring considerably less than 500 ms, and deduced that this salvages free will (or at least free wont!). That conclusion is undermined by the observation that countermanding processes are just as automatic as the original movements (Carpenter and Williams, 1995). If neither a motor act's initiation nor its last-moment veto are freely willed, however, what advantage would they confer? How could unfree choice be more useful than the mechanical discrimination performed by feedforward neural networks, or by creatures devoid of consciousness? The benefit is profound: *real-time choice* (or *veto-on-the-fly*, as it could be called), *even in the absence of free will, would still be an enormous advantage to the animal*.

An insect also explores and makes choices. But when about to make a move, it never suddenly *realizes* the significance of its intended action and then vetoes it, even though the vetoing might perforce be mechanical and deterministic. This ability could sometimes make the difference between life and death. We, and our sufficiently close evolutionary relatives, do possess such a mechanism, as the above-cited studies demonstrate. The Carpenter and Williams work merely goes farther, by showing that free will need not be invoked.

*Why should exploitation of this deterministic mechanism produce consciousness?* Why could this unfree process not be carried out unconsciously? The answer lies in that word navigation. As those ancient mariners navigated the globe, their routes were dictated by environmental feedback; encountering an obstacle – impenetrable isthmus, unfriendly natives – they changed course, as recorded on their charts. Our body/mind systems can likewise switch tactics and the process, although deterministic, also relies on feedback, from the environment or from our recollections of it, or from both simultaneously.

But what is our system's counterpart of those indispensable charts;
where is our record of the muscular route recently taken? It is present, though only fleetingly, in the muscles themselves. Their states, and the rates of change of those states, are perpetually monitored by the tendon-organ/muscle-spindle apparatus, and although the mechanism is surreptitious, the overall system is aware of these parameters (Goodwin et al., 1972; Lethin, 1977). The record persists over the span of very short memory (Edelman's remembered present, 1989; Humphrey's thick moment of time, 1992). Our systems are thus continually apprised not only of our surroundings, but also of their significance for us; they satisfy Sommerhoff's (1996) canonical requirements for conscious awareness!

What is the underlying neuronal circuitry? It was suggested (Cotterill, 1997) that consciousness requires planning of movement to be actively proceeding, and that the phenomenon arises through signals passing around a closed circuit consisting of the sensory cortex (SC), the premotor area (PM), and the thalamic intralaminar nuclei (TIL). In the absence of coupling to external stimuli, activity in this circuit was conjectured to underlie thought. The model invoked schemata, a schema being a reproducible co-activation of neurons linking a specific pattern of motor-planning activity (in the PM) to appropriate SC activity (reproducible because schemata are held in memory). Recruitment of an appropriate schema, or set of schemata, during overt motor exploration of the environment, or its simulated surrogate (i.e. thought), is presumably a self-organizing process (Haken, 1996); whence the temporal latencies measured by Libet et al. (1979) and by Carpenter and Williams (1995).

Purpura and Schiff (1997) suggested that awareness additionally requires a second closed circuit, also comprising the SC and PM, but including the anterior cingulate (AC). This does not jibe with the fact that bilateral removal of the AC, for the relief of chronic pain, does not preclude consciousness. But the AC could be intimately involved in the above veto-on-the-fly mechanism. It is noteworthy that there is a connection between the AC and the nucleus reticularis thalami (nRt) (Cornwall et al., 1990; Lozsádi, 1994). The nRt regulates activity in the thalamus, including the TIL, thereby directing the focus of attention (Crick, 1984). Finally, the AC is involved in pain perception (Talbot et al., 1991). Collectively, these facts suggest that this second circuit could indeed mediate the above veto function, through the AC forcing the nRt to divert attention toward possible danger, somehow depressing the motivational level below the threshold for movement (see figure 1).

With consciousness emerging as an indispensable servant of the unconscious (in higher species), one could call this quasi-behaviourism. The fascinating thing is that by requiring members of sufficiently advanced species to be a captive audience of their own motor acts, the evolutionary innovation of veto-on-the-fly gave its possessors a decisive advantage, and at the same time permitted their systems to acquire knowledge
about the environment through one-shot learning. This contrasts with the more gradual conditioning seen in creatures devoid of consciousness.

Finally, turning to a particularly venerable issue, the internally-simulated navigations (Damasio’s as if processes, 1994) mediated by the SC-PM-TIL-SC loop can draw upon the predictions provided by the cerebellum (Miall et al.’s what if processes, 1993) and the planning capabilities provided by the prefrontal cortex (Ingvar’s memory of the future, 1985), while automatically notifying the body of their significance. Seen in this light, there is no problem of body/mind, merely a situation of body/ability-to-simulate-body's-interactions-with-environment.

Figure 1. The core circuit that mediates the veto-on-the-fly mechanism comprises the brain regions shown here, the sub-circuit consisting of the sensory cortex (SC), the premotor area (PM) and the thalamic intralaminar nuclei (TIL) serving consciousness itself. This is supported by the observation, by Kinomura et al. (1996), that the PM, TIL and SC are all active during attention. It should be noted that the link between the latter two components passes through the nucleus reticularis thalami (nRt), which acts as a gate (its inhibitory effect here being indicated by the black colour). This gate, in turn, is under the control of the anterior cingulate (AC), and also of the brainstem reticular formation (not shown), the latter dictating the sleep-wake cycle. The AC is known to be involved in the perception of pain, so it is well suited to the job of applying the veto. It is important to note, however, that consciousness is not dependent upon the presence of the AC; indeed, bilateral cingulotomy patients are as conscious as normally-endowed people.

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