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Editorial

Necessity of Brain Function in Animals

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Claude Bernard proposed the concept of the milieu intérieure as a field inside a body separated from the external environment by a boundary that maintains a quasi-steady state through homeostasis [1], and Cannon developed this concept of homeostasis and analysed its mechanisms in detail [2].

Homeostasis, as a mechanism for maintaining their own existence against disturbances from the environment, is a fundamental function for living organisms, whether they are plants or animals. This function is considered to essentially consist of negative feedback that detects deviations from the desired quasi-steady state and changes the state in the direction of correcting them. This mechanism does not necessarily require a high level of intelligence, as a simple thermostats can regulate temperature. Negative feedback is the mechanism pushes back deviations from the desired state until they cease to exist, it is sufficient to have a device for detecting changes in state and a corrective device directly connected to it.

Quasi-steady states or steady states differ from equilibrium states in that free energy must be consumed to maintain them in accordance with the second law of thermodynamics. Even living organisms must, naturally, obey the second law of thermodynamics, they need to capture some form of free energy to compensate for the production of entropy associated with their life activities.

If the quasi-steady state satisfies Prigogine's principle of minimum entropy production [3], it can be a favourable state for the survival strategies of living organisms, at least in the short term, because it consumes less free energy. If the definition of quasi-steady state is broadened taking a slightly relaxed view, it may be possible to include habitual routine behaviour as it is chosen to minimise the loss of free energy.

Plants obtain free energy to maintain their life activities through photosynthesis, so once established in a good environment, they may not need advanced brain-like intelligence for homeostatic activities, such as adjusting water and ion concentrations in the body by opening and closing stomata.

On the other hand, animals have to consume free energy just to maintain a comfortable quasi-steady state, so they have to deviate from it at some point and take action to eat. While, for herbivores, relatively slow movements are sufficient to eat plants that do not move, carnivores need to move quickly before their prey can escape. Herbivores also need to escape quickly to avoid predation by carnivores.

For this rapid departure from the quasi-steady state, positive feedback is considered to be at work to increase small fluctuations and lead to larger movements, in contrast to the negative feedback that had been working to suppress small fluctuations until then. Positive feedback is thought to be at work behind sudden movements, and involuntary movements such as sneezing, yawning and hiccoughs are typical of this, and are also characterised by the fact that they do not stop even if one tries to stop them in the middle.

Positive feedback also does not necessarily require a high degree of intelligence, as a simple mechanism can only be triggered automatically when a parameter exceeds a defined threshold, causing a sudden change of state in a predetermined direction. The aforementioned hiccups, yawns and sneezes are also considered to operate subconsciously in the central nervous system using neural networks below the hypothalamus without using the cerebral cortex.

The mathematician René Frédéric Thom proposed the concept of catastrophe [4,5], which drew attention to the mechanism by which a quasi-steady state maintained by negative feedback can be rapidly altered by positive feedback. This mechanism is also at work in binary decisions, such as fight or flight, and in periodic movements such as heartbeat, walking and breathing. Unlike negative feedback, behavioural choices with positive feedback are more complex. The choice of the timing of its triggering is important first. For example, if the animal approaches its prey and at a certain point decides to pounce, if it does so too early, the pounce distance will be too long and the prey will run away; if it does so too late, the prey will be aware of the pounce and run away before it can pounce.

Control by negative feedback maintains a quasi-steady state, which should result in relatively low free energy consumption if Prigogine's principle of minimum entropy production holds, whereas the use of positive feedback results in the temporary consumption of a large amount of free energy.

Changes in the environment or deterioration of internal conditions, such as starvation, often make it difficult to maintain a comfortable quasi-steady state. If we believe in the principles of evolutionary theory, it is thought that animals at the forefront of evolution, including humans, judge a state favourable for the conservation of the species and make behavioural choices to achieve it. If the value evaluation of the desirability of this state of affairs is defined as Quality of Life (QoL) [6], it should be comfortable if the QoL remains sufficiently high, and it should be advantageous for the survival of the individual and the survival of the species if the choice is made so that this situation continues for a long time. The quasi-steady state with negative feedback is advantageous in that it minimise the consumption of free energy, and therefore the quasi-steady state in the widened sense with the highest QoL just described is chosen, but if there is a change in the assessment of QoL due to changes in the environment or internal conditions, the system must change to a higher QoL state, but it must then be able to see a profit commensurate with the higher free energy consumption required.

Stress, as described by Selye [4], can be regarded as an alarm that a quasi-steady state has disturbed and is becoming difficult to resolve. When stress is brought to consciousness, a decision is required to make a choice between continuing efforts to maintain the quasi-steady state as it is, or giving up on it and taking free-energy-consuming actions (including positive feedback) to achieve the next suitable state. continuation of the negative feedback to quasi-steady state is chosen if it can be expected that the stress will disappear over time as the gap resolves, or any other better action does not exist. Otherwise, the decision would be to move out of the quasi-steady state. Though one is free to choose any state as the next goal, it must at least be possible to expect that the situation arrived at will be better than the original state (e.g. more convenient for life support), and choosing the best of these will require a high level of intelligence. One reason for the development of the brain in higher animals may be that it serves as an information processing equipment to judge the value of the possible options for making the right choice.

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