SENSORIMOTOR INTELLIGENCE, MOBILITY AND THE BRAIN

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Life and Mobility

A few centuries years after Heraclitus Aristotle claimed life involved motion. About two millennia later Einstein proved that everything in the universe moved, relative to everything else, from rocks, mountains, and microbes, to large organisms. And his great equation: $E = mc^2$, showed that mass itself does not stand still. Instead it is only a relatively stable form of energy. And the universe is incredibly dynamic energy field. Evolution is a way of saying that over time nature throws up new species as old ones die off. And, philosopher-scientist Charles Peirce noted over century ago, it is a game of chance (). Then about 60 years ago Bernard Lonergan, a mathematically inclined Jesuit, advanced Peirce's insight further by arguing that evolution involved two probabilities: the probability of a species' origin or emergence, and that of its survival, the former being a matter of chance and the latter, of natural selection (121f). Natural history however suggests the probability of the emergence of life from inorganic nature was rather low, for it took billions of years.

But once living species emerged, they moved themselves, in contrast to inorganic matter like rocks. But their environment was full of threats as well as opportunities. So mobile organisms faced high survival risks. The more they moved, the greater the probability of injury, death and even extinction. If a microbe for example entered a poisonous chemical environment, it would be killed. An early solution to this problem was for micro-organisms to generate large populations. So, while the survival of many individuals was not high, the species would enjoy a much higher survival probability, and would continue to reproduce. This however required that they remain very small, for if they got larger, their numbers would likely significantly decrease. But microbes did get larger. Multi-cellular forms like amoebae emerged. Their numbers were still high. So their survival probability was high enough for such species to survive. It would seem the probability that larger species would emerge was high, but not that of their survival. In fact larger mobile multicellular organisms emerged about 570 million years ago. Given their mobility, they needed cognitive powers if they were to survive as they moved around unknown, threat-laced environments. In fact the realm of the unknown is far vaster than we like to think. Indeed much of the universe is a field of what Thomas Homer-Dixon calls unknown unknowns (2000: ch 7). Incidentally, his treatment of the unknown is important, for it shows that absolute skepticism, the claim we cannot not know the world, to be a non-starter as a credible, testable theory. On the contrary, if we couldn't know the world, we could not survive. We would never have emerged, for predecessor species also could not have survived. But what Homer-Dixon has shown is that we can even know something about the unknown. And the discovery that most of the universe is either dark matter or energy adds even more to our knowledge of the unknown. And the extent of sensory and cognitive powers in nature is vaster than most of us realise.

The more mobile an organism, the greater the environmental threats it faced, many of which were difficult to detect. As organisms grew in size, ever larger species ranged ever more widely, in largely unknown high risk environments. Worse, larger species have much smaller populations than micro-organisms. So, as LBO species ranged ever more widely their survival risks dramatically increased. Since sensory powers enabled mobile LBO species to better detect and sort environmental opportunities and threats they were survival critical. Absent multi-modal sensory cognitive powers, mobility is blind and risky. Greater mobility would mean more accidents and injuries, fast leading to death and extinction. This was especially true for LBO species, given their high mobility and low populations. Early LBO species may not have had cognitive powers, but very soon I suspect sensory organs like vision, smell and hearing, taste and touch evolved in LBO species, vastly increasing their survival probabilities. Now, mobility in organisms is not limited to gross body movements like moving one's head, limbs, walking and running. It also includes internal movements, such as the dynamics of organs like the heart, various glands, bones, and the constant flux of blood and hormones.

All organisms are mobile, but early micro-organisms lacked sensory organs and nervous systems. As organisms got larger and more mobile, they encountered, new, different environments, putting their survival, and the species, at risk. **L**BO species moving about in different environments need nervous systems that support their multiple intelligent sensorimotor, psychological and social as well as organic and bodily functions. It needs to learn remember, foresee, communicate, interact with other actors. All on top of ongoing neurally regulated autonomic non-voluntary processes. LBO species are very complex organisms: they must have motor control, skeletal, muscular, observational/cognitive, energy consumption / food digestion, species reproduction, and many other organic functions. LBO species are chemically complex. To enable LBO species to sort environmental opportunities and threats and survive sensory organs and nervous systems evolved.

The need for rapid responses mean that unconscious automatic processes evolved first. Multiple neural regions appear to support motor functions, which are quite complex (Dubin 44, Lecture 5; Sweeney, 146, 152ff). The brain smoothly issues motor responses to sensory reports. Sensory receptor input IN trigger Motor behaviour OUT output responses. *Sensory* inputs are *afferent* neural processes; motor outputs are *efferent* neural processes (Wiener, 43f). Sensory information IN, motor behaviour OUT is a key aspect of neural process. Somato-sensory and motor cortices are contiguous, next to each other at the top of the brain (Dubin, 35, 39). Sensorimotor connections are only possible in organisms with a BBS. Sensorimotor connections are an evolutionary basis for the emergence of intelligence in numerous species. Only organisms with brains can be autonomous, intelligent and make choices. Autonomy means that an actor's brain only controls its own processes and behaviours, not those of other actors. We can influence another's behaviour, but we cannot directly control their thoughts, feelings, bodily movements, choices, or actions. This is as true of mammals, birds, and fish as of humans.

Sensorimotor Cognition

Interacting with the External World: "A critical function of our brains", Sara Solla said, "is to provide an interface with the external world. This interface has two fundamental components: the unconscious automatic processing of sensory information and the control of movement" (Solla, 491f). Brains had to enable organisms to adapt to external environments, and interact with other actors in the environment. For nature is full of surprises, which can be threats or opportunities, and most are unknown and unpredictable. A neural code therefore must interpret external environmental reports from the senses and generate appropriate responses. For, Donald Hebb claimed, "Behaviour is primarily adaptation to the environment under sensory guidance. It takes the organisms away from harmful events and toward favourable ones, or introduces changes in the immediate environment that make survival more likely" (in Holland, 58). The implication of Hebb's comment is that sensory guidance requires organisms to interpret environmental messages, distinguish those that favour its survival, from those that threaten it, and respond accordingly by enacting survival-enhancing behaviours. This requires an organ that can both interpret sensory messages, assess their potential impact on themselves, and formulate and rapidly enact survival-enhancing behavioural responses. Sensory and motor functions in fact are in neighbouring regions at the top of the brain (Dubin, 39f; Sweeney, ch. 5).

Mobility needs controlling, for absent environmental information receiving and interpreting powers organisms were blind, and their survival at critical risk. So sensory organs evolved in LBO species. Sentience is the basic form of cognition found in highly mobile LBO species. It involves interpreting messages in various physical media: light (vision), chemical**s** (smell, taste), sounds (hearing), physical properties (touch, handling). Sentient powers evolved to enable mobile organisms to detect, observe, and interpret environmental phenomena. Early micro-organisms had the basics of visual and chemical sensing. Early flagellate species had an 'eyespot', and sponges responded to touch.

Large-Bodied Organism (LBO) species evolved two key types of sensory powers: distance senses: vision, smell, hearing; and contact senses: taste, touch, and their skin. They also evolved internal proprioceptive body sense, and neural body map—supported by the PNS. But Sensory detection of environmental phenomena is not enough to ensure survival. For millions of years micro-organisms moved around their environments. Early micro-organisms at first likely could not perceive their environment, and that, Aristotle noted, is dangerous. The probability is high that cognitive powers would soon emerge in such species. By 'cognition' I mean information receiving, interpreting, sorting and error-correcting processes, plus memory. In a word, observing and learning about the world, and retaining what one has learned for later recall, summed up in two concepts: sentience and memory. By 'sentience' I mean all sensory functions. So sensory cognition is multi-modal: visual, aural, chemical, and contact/touch cognitive capabilities. In fact multiple sensory capabilities emerged in micro-organisms: the basics of vision, or chemical reactions to light. They move up toward light, down if it's too bright. Early flagellate species, it seems, had an 'eyespot', and sponges responded to touch. Various sensory organs use different media to report information about the world: light, sound, chemical, physical. Thus we get sight, hearing, smell, taste and touch. Scents go directly to the hippocampus, which supports memory. So smells evoke memories. Vision too is very important. The eyes transmit information about objects, their location, movements, size, shape, colour and texture.[7] 100 million rods and cones send visual messages about shape, movement, and colours respectively, to 15 brain areas via 20 parallel neural pathways.[8] Vision, smell and hearing were especially important because they enable LBOs to detect objects at a distance; while touch and taste require contact with objects. Vision, smell and hearing moreover also enabled LBOs to communicate with other organisms, further enhancing their survival chances.

Hearing is an engineering masterpiece. Many acoustic detectors are packed in a small pea-sized space. There they 'transduce' minute vibrations in the ear to the auditory cortex and on to other neural regions.[8] Auditory signalling in the brainstem moreover is 1000 times faster than visual receptors. Hearing also helps an organism to localize objects by estimating its horizontal distance and vertical elevation.[9] Hearing is in addition a key social communication competence, as central to wellbeing as vision. Indeed hearing loss is often more socially devastating than blindness.[10] The auditory system is 'tuned' to conspecific voices. Sound has several features: waveforms, phases, amplitude (loudness), frequency (pitch), and harmonics. And LBO species are sensitive to all of them.

Taste and touch in contrast involve contact with objects. Taste receptors in the tongue detect five basic tastes: sweet, salt, bitter, sour, umami. Smell detects chemical information re animals, plants identify food, mates, noxious substances, prey and predators in the environment (eg tigers), one's own and other's voices. Humans can track low concentration of scents at long distances. Smell and taste detect chemicals, and sort them into pleasant and unpleasant odors and tastes, triggering pleasure and disgust responses in organisms and leading animals to avoid the latter, instinctively sensing that they threaten their health. Touch and the skin require contact with objects sensed. The skin is also a sensory cognitive organ. Mechanoreceptors in the skin report on pain and heat. Nociceptors report the location, intensity (acute or lingering) and the type of pain (). The skin also lets light in, eg, in comatose patients.[11]

A new cognitive power likely evolved about the same time: conscious sentience and pain / pleasure sensations. For it was highly probable (~100%?) that multi-modal sensory cognitive powers evolved in LBO species. The evidence for consciousness in animals, I note, is the same as evidence for awareness in other humans; and we probably inherited it along with other cognitive powers from our large predecessor primate species, including marine and air borne species. In fact Peter Godfrey-Smith has extensively studied embodied consciousness in the octopus, showing its eight arms, which are full of nerves, perform cognitive functions.[12] A corollary of this argument is to reject the claim that the 'mind' somehow emerged independent of the body and the brain. It does not make sense, for any large species that evolved would have to have powerful cognitive interpretive powers and a memory, in addition to multi-modal sensory powers, in order to reduce its survival risk to acceptable levels and avoid extinction.

THE BRAIN & BIOREGULATION

What is the brain's job? The principal function of brains and nervous systems is to ensure the survival, reproduction and wellbeing of the organism. To this end the brain unceasingly regulates and controls the body's numerous organic processes and bodily movements (see Appendices). To that end the brain also regulates a bewildering variety of neurochemicals that affect a variety of organic processes (like blood circulation, breathing, digestion), psychological functions (like sensation, perception, learning, memory, emotions, feelings, attention, awareness), and executive functions (goal setting, option scanning, decision making, behaviour, action, learning from experience and memory) and interacting with other Intelligent Social Actors (ISAs). The brain constantly monitors, controls, regulates and coordinates the body's organic, biological, psychological social processes and bodily behaviours every second of every day. To do this requires all the resources of the brain, not merely 10%, as an old myth suggests.

While constantly regulating organic processes and chemicals the brain enables and supports numerous other functions: sensory perception, bodily movements, intelligence, learning, memory, decision making, language, emotions, feelings, rewards, pains and pleasures, waking and sleeping. The brain can not do all this if it were separated from the body. On the contrary, brain and body must constitute one seamlessly integrated intelligent actor. Regulating and controlling all these organic and psychological processes and behaviours is impossible absent the brain's dynamic integration with its body. Brain and body in fact constitute a seamlessly unified Intelligent Sociobiological Actor, an actor who can adapt to changing environments and interact with other actors. Together they constitutes one 'whole organism" (Damasio). Unified BBS facilitates the brain's intelligent control of the body's organic psychological processes and movements. It is the neurobiological basis for an Intelligent Sociobiological Actors, whether animals or human. Absent unified BBS, I submit, Intelligent Sociobiological Actors are not possible, and animals and primates and humans could not have evolved. But there are limits to their partnership. Each organism or actor has its own brain and body, united in their own partnership. A brain can only regulate and control its own body, not that of any other actor, nor the environment in which it lives.

The need for organisms to simultaneously and continually control their body and its multiple internal systems, while also interacting with the external world called for and internal control system to evolve, for, that is, a nervous system. But to meet these demanding requirements neural processes, needed a set of rules, as well as significant flexibility. They needed a neural code, which could both enable organisms to regulate their multiple internal systems, reproduce the next generation, communicate and live together with each other and with other species, and adapt to changing environments. To these ends the brain had to not only have internal regulatory, external and internal message processing capabilities, but also social powers like interpreting body language, facial expressions, empathy, mental processes neural mirroring. The neural code enables the evolution of conscious cognitive and executive processes in the brain. This may be one of its most important functions, but social life and communication will be explored further in coming chapters. In sum brains regulate and coordinate internal organic processes, bodily movements, all the while monitoring and responding to its changing external environment, and enabling interaction with others. So it needs to be a very flexible, indeed plastic, organism.

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