Inner Space: The Strange Extra-Arachnoid World Beneath the True Dura

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"The fact that dolphins speak is not a recent discovery. Aristotle knew it 23 centuries ago. Since his time, however, the land-bound civilization of the West forgot that there were indeed voices in the sea ..."

Dolphins: The Undersea Discoveries of Jacques-Yves Cousteau, 1974.

"The brain and spinal cord are protected by three membranes called the meninges."[1]

ALL well and good, but what is the function of potential (i.e. empty) space? One labyrinthine space within our skulls and spines may be the site of assorted syndromes of high morbidity and mortality.[2] These syndromes occur at all ages, and frequently mimic other neurologic diseases. This narrow continuous space, on both sides of the falx, above and below the tentorium, through the foramen magnum, from forehead to sacrum, is called the subdural space. It holds little interest, until it becomes the site of disease, when it often steals the show.

I explored new spaces as a boy in Brooklyn Heights, where Washington's colonial army escaped British warships in the fog. I often crossed the bridge to the Emerald City, riding my bike over to the Hudson, awed by the grand Palisades with its gargantuan roller coaster, rivaling Coney Island's feared Cyclone. In Manhattan's corridors were living four dimensional spaces transformed by sunlight, shadows, night, screaming El trains and moving subterranean passages with vibrating rails. I drew maps of these crowded noisy spaces, rising up from the bowels of Earth into skyscrapers, towers, bridges and cliffs, land maps drawn from the Heights. In a moment it could be abolished by fog, permitting escape.

What if all our maps were imagined by some sea creature? How would reality change? We could not call it geography, the mapping of land. Connie and I went swimming with dolphins in Cancun, directly feeling their playful intelligence and speed. Dolphins are warm blooded beings, who breathe through their lungs, as Aristotle knew. As a UCLA neurosurgeon, a neighboring anatomist showed me his prized dolphin brain. Human in size and convolutional complexity, dolphins sport larger temporal lobes than ours, the mammalian sites where all senses converge, especially sonar. Dolphin auditory cortex is larger in area than man's, and their acoustic nerve is much larger, making it the most prominent cranial nerve. Dolphins hear 150,000 vibrations per second (150 Kilohertz), 10 times the upper limit of human hearing. Underwater dimensions, pressures, social dolphin chatter and humpback whale songs merge in these elegant brains with emotions unknown. Dolphins also have stereoscopic vision with highly mobile eyes, and good vision in water and air. How do spaces, not landed boundaries, look to such natural beings? Can we search our own secret spaces in unconventional ways? Apollo the sun god first appeared as a dolphin to the most ancient Greeks of Crete, establishing their sanctuary to Apollo at Delphi, where waters merge with light. The oracle of Delphi honors the dolphin's name: *Delphinus delphis*. In Veranasi, called Benares, "older than history" by Mark Twain,[3] Connie and I sailed the Ganges. Blind dolphins swam its sacred waters, flowing from the Himalayas to the sea. Hindus come to the Holy River, facing East to worship many gods. Eldest sons, heads freshly shaved, bury their dead in its waves, burned bodies taking the shortest route to Eternity. What did dolphins know that brought them here? What unsuspected spaces do we inhabit? Or inhabit us? To what dimensions are we blind?

Neurosurgeons know a strange inner space we call "subdural," named by reference to dura, the terra firma of the skull. Ancients called the Mediterranean "center of the world," the water between the lands. We cannot help our land-based reference from which all things are named and

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measured. But it is the inner space itself, locked between true dura and arachnoid that contains acute and chronic subdural hematomas, subdural hygromas, effusions and empyemas, from infancy to octogenarian, from time before memory to the amnesia of great age. Neurosurgeons see them all, the traumatic, alcoholic and coagulopathic subdurals, infants with enlarging heads, seizures or failure to thrive, abused children with unequal pupils, adults with subdurals that mimic syncope, TIA, stroke, brain tumor, encephalitis, dementia and psychosis.[2] The history of trauma may be forgotten only to be recalled days after subdural blood is drained.

This subdural world is a hall of mirrors, each reflecting its own unique reality. It is that potential world between Latin "dura mater" and Greek "arachnoid," the potential space between the hard fibrous envelope or mother of meninges, and the delicate spidery web beneath which flows pure cerebral water. With every heart beat and each carotid pulsation the brain pulsates in its dark obsidian night, floating within and without, bathed in its clear saline. Over each convolution, a mini-pulse is transmitted through subarachnoid water to the extra-arachnoid space, marking inaudible time, time infolded into inner spaces. What is potential space? What is potential time? Does Nature abhor a vacuum? Or is it we ourselves, with our visual terrestrial brains, who feel obliged to fill any emptiness with something? Astrophysicists now believe cosmic spaces repel other cosmic spaces by dark energy, so galaxies fly away from one another in spite of their mutual gravitational attraction.[4] Timespace is filled with invisible dark matter and dark energy. String theory created ten or more microdimensions that make mathematical sense at the tiniest levels, combining relativity with quanta in unimagined vibrating geometries.[5] We grasp potential space only by its boundaries, like seeing an invisible black hole in the details of its event-horizon.

We call our intracranial potential space "subdural," but a better term is "extra-arachnoid," the empty no-man's land between soft, spidery membranes within and tough dura without. Dura is a double fibrous layer; the outer is the periosteum of the skull, the inner being the "true dura mater" that forms the falx and tentorium. The dura also forms the pathway for the dural venous sinuses. The arachnoid is the outermost anatomic blood-brain barrier,[1] containing circulating subarachnoid fluid. The innermost blood-brain barrier resides in the endothelial lining of capillaries within the central nervous system.[1] The blood-CSF barrier exists both in the choroid plexus and in the arachnoid.[1] The narrow potential extra-arachnoid (subdural) space is a continuous narrow valley, forever outside nervous tissue. The strange multidimensional geometry of this inner space is crossed by bridging veins to skull, scalp and to intradural venous sinuses, by arachnoid granulations into venous lacunes and venous sinuses, and by passing cranial nerves and blood vessels (e.g. carotid arteries) at the skull base. As the arachnoid membranes move with brain pulsations and CSF flow, so too the extra-arachnoid space undulates, marking time.

Whenever it is bleeding, injured, inflamed or infected, our potential inner space takes on a life of its own. CSF diffuses across the thin arachnoid toward subdural macromolecules of hemoglobin and cellular debris, filling the empty valleys with fluid at the expense of brain. Motion is in one direction, toward the potential space, since large protein molecules cannot pass through the tight junctions of mesothelial cells of the arachnoid membranes, unless the arachnoid is also injured. Once begun subdural collections grow, especially if subdural bleeding continues. At ten days visible subdural fibroblastic membranes are seen at surgery. As these neomembranes thicken they become increasingly vascular. Fragile new vessels grow into these neomembranes, and are a source of continued bleeding. The neomembrane capillaries are highly permeable to albumin, leading to osmotic growth of the subdural mass. Subdural membranes secrete fibrinolysins, liquefying clotted blood.

Imagine a dolphin's view, as dolphins swim the flowing cerebral waters, leaping up toward the translucent arachnoid from within, diving down into Sylvian fissures, down to basal cisterns, down through the Great Foramen, then up into ventricles to see the brain make sparkling water out of blood! In their swift passages our dolphins discover magical doors, where no blood-brain barrier exists. The subfornical organ beneath the fornix, the area postrema in the floor of the fourth ventricle, and the organum vasculosum of the lamina terminalis at the anterior third ventricle, are open doors with no blood-brain barriers, chemoreceptor sense organs for blood-borne substances.[1] Sonar detects these magical doors, silent openings in the midst of turbulent flow, shortcuts to Paradise in the Ganges.

Chronic subdural hematomas are deceptive. Forty percent of chronic subdurals are admitted with an erroneous diagnosis. A chronic subdural may have an insidious or an acute clinical presentation. Surgical drainage succeeds in 80% to 90%.[6] Early diagnosis correlates with a favorable prognosis.[7] Since the extra-arachnoid space is nonadherent, empty and extensive, no skull fracture or lacerated artery is required to induce the gradual formation of a large chronic subdural collection of blood. Minor traumas are forgotten.[6] Aspirin for headaches helps it slowly grow. Chronic subdural bleeding from a leaking vein converts the extra-arachnoid empty space into a dynamic living protoplasmic creature, with developing vascular secreting neomembranes, enlarging and loculating, producing a myriad of symptoms. Worsening headaches after trauma, persistent postconcussion syndrome, poor attention,

chronic alcoholism or drug abuse, anticoagulant therapy, difficulty walking, unexplained falls, dizziness, seizures, amnesias, anxiety, personality change, hallucinations, dementia, sudden or transient weakness, hemiparesis, paraparesis, numbness of limbs, syncope or aphasia, double vision, vomiting, papilledema, unexplained fever, bradycardia, difficulty breathing, stupor and coma are among the many manifestations of this great extra-arachnoid mimic, the extraordinary actor, the chronic subdural. All it takes is a high index of suspicion, a quick CAT scan, and an early burr hole! Not to mention a new appreciation of inner space. ...

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