The art of medicine

Unexpected life lessons from cardiac anatomy and physiology

Cardiac tissues are a curious mixture of nerve and muscle fibres, a fusion of electrical anticipation and muscular release. Their surfaces contain molecular clocks that keep time by shuffling charged particles of calcium, potassium, and sodium across their cell membranes. Ion by ion, the electrical potential accumulates, as millions and billions and then trillions of ions gather. Then, suddenly, one more particle is simply too many, and a point of no return is reached. The electromagnetic pressure is too great. The gates are thrown open and suddenly let the ions all crash back in, causing an electrical current to fire across the myocardium. Systole has begun, as the individual fibre and then the entire heart contracts.

Like a heart, one's life requires a certain cadence, with alternating periods of systole and diastole. Sometimes I feel like one of these cardiac fibres, with periods of gathering restlessness followed by intense activity, and then rest again. The heart has much to teach us, by example. Muscles and people need rest between periods of intensity. Observe what happens when the example is ignored: In certain open, infected wounds, the bacterium *Clostridium tentani* can grow. This organism produces a unique toxin that causes muscle cells to fire uncontrollably, in continuous systole. These contractions are called tetanic, and the name of this condition is tetanus. The common term "lock-jaw" refers to the uncontrolled clamping of the masseter, or jaw muscle. The same situation occurs in several muscles in the body, and the condition can be lethal. The lesson: diastole is critical to survival.


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Helen Taussig (1898–1986)

As a paediatric cardiologist, I've often reflected on the many dimensioned wisdom of the heart—not only the life lessons from the metaphorical emotional meanings attached to it, but those emerging from the study and appreciation of its actual physiology. Only recently, I played with a young toddler who had a cyanotic congenital cardiac defect with a transcutaneous oxygen saturation that would have flummoxed me. Oliver Sacks, the neurologist, writes that the joy of doctoring comes not from concentrating on a patient's disorder, but on his adaptation to the problem. Children with heart defects have enormous physiological resilience. They frequently have enormous psychological resilience. Over the years, I have grown to love cardiology for this reason: it suggests to me that no problem is insurmountable. There in the cardiac ward, I was seeing a child do the impossible, living with an oxygen concentration previously unimaginable to me. And he was playing in front of me.

It's an unlikely teacher, this organ to which I devote my life's work. The heart is a highly disciplined structure, performing its task over and over again. The kidneys produce urine, but also regulate blood pressure, help mineralise bones, and even determine the amount of blood the bone marrow manufactures. The liver makes cholesterol, detoxifies wastes, and makes salts to break down fats. The pancreas regulates body sugars and makes a bevy of substances to help us digest foods. But the heart more or less pumps blood day in and day out, without engaging in extraneous activities. And yet it also leaves acoustic evidence that, to the trained ear, makes every heartbeat into a diagnostic fugue. A small trill, an extra reverberation, or a miniscule click provides important supporting information about possible structural problems with the heart. The heart is a very public organ. Almost every event that occurs—blood entering a chamber, a heart valve opening or closing, or an extra blood vessel where it shouldn't be—leaves acoustic evidence that can be collected with a stethoscope, still another reminder that one must, first and foremost, listen to the patient.

These sounds are difficult to describe, and some resort to curious and sometimes inadvertently hilarious analogies. Listening isn't easy, and requires an active intelligence from the listener. For example, in his classic treatise *The Art and Science of Bedside Diagnosis*, Joseph Sapira offers the following advice to the budding clinician, "The murmur of aortic stenosis has been likened to the sound of a steam engine chugging up a hill. For prairie dwellers and young persons who have never heard a steam engine on an upgrade, the grunt made by older persons of Mediterranean stock as they settle their arthritic joints into a chair is a passable substitute." And of course, listening to the world isn't only an acoustic skill, but one that is so subtle as to be almost emotionally ethereal. Helen Taussig, the pioneer of paediatric cardiology, had even more impressive diagnostic powers, since she had to make her diagnoses in the 1940s without echocardiograms. Although she became almost completely deaf, she compensated by using her fingers to feel the sounds.

Consider, also, the things people will do to learn the secrets of the heart, to unlock its meanings, to set it right. Correctly surmising that a tube inserted into a vein in the arm could get to the heart in 1929, the eccentric German physician Werner Forssmann inserted a long urinary catheter deep into a vein in his own arm, until he thought it reached its destination. (A nurse had tried to stop him from performing this reckless experiment on himself, but he subdued her and tied her to an operating table.) He then walked a flight of stairs to a radiology machine, and took a radiograph of himself showing that the end of the catheter really had reached his heart. In this bizarre manner, Forssmann performed the world's first cardiac catheterisation, for which he later received the Nobel Prize. And who could not be moved by the first attempts at open heart surgery done by C Walton Lillehei, in which parents' systemic arteries and veins were directly anatomised to their children with congenital cardiac defects. In these cases, parents served as the living bypass machines for their children, quite literally allowing their hearts to beat as one, with their fates irrevocably entwined. Such procedures were, as Lillehei would later reflect, the first in human history with a potential for a mortality rate of 200%.

Each minute, the heart pushes about 5 litres of blood into the aorta, and ultimately ejects almost 200 million litres in the typical lifetime, enough to fill a modern petroleum supertanker. And yet, at any moment for many people, the cardiac cycle goes awry, devolving into fibrillation resembling a bag of worms attempting to wriggle free. Roughly one in 20 adults have asymptomatic, short periods of ventricular tachycardia each day, and those with genetic defects of their potassium channels live each day reposing under their own sword of Damocles, always aware of the transience of their existence. Some live their lives in fear, as various subtypes of their disorders allow the most benign daily experiences—the buzz of an alarm clock, the sudden touch of water in a swimming pool—to precipitate lethal arrhythmias, from which only a precisely delivered shock can jolt them back into the world of the living. From this horrible existence, perhaps there is a reminder, as Henry David Thoreau might ask, for us to constantly ask whether we are truly living sincerely, as if every day could be our last.

Centuries ago, blood was thought to have sloshed in a disorderly manner throughout the body, and the heart considered a porous organ of no clear mechanical significance. William Harvey, a 17th-century Oxford physician, examined the blood vessels of almost 80 different animals, including dogs, fish, and man, and discovered an unusual property of veins. When he forced water through veins towards the heart, the water passed without resistance. However, when he tried to inject water in the opposite direction, it would not pass. Harvey discovered a principle clear to anyone who's played a reed instrument; you can only produce results by blowing air in one direction through the instrument's reed. Small valves similar to saxophone mouthpieces punctuate veins. Harvey realised that blood circulates in a single direction, and that the heart is a mechanical pump.

Periodically, I observe the opening of a person's chest during cardiac surgery, and it is always a magnificent and terrible sight. Not so long ago, I watched a young, brain dead teenage boy whose heart continued beating, oblivious to the absence of its master. Slightly larger than a softball, the adolescent's heart alternately swelled and collapsed in an orderly top to bottom fashion, about once every second. It had done this without pause for the past 17 years, hidden until today. The light from the overhead lamps now brightly illuminated the heart. 5 feet away, I could make out its anatomy. The surface was largely covered by glistening yellow fat, its normal coat. A few worm-like structures were also visible below that fat; these were the coronary arteries, the blood vessels that give oxygen to the heart. Soon, the surgeons infused the ice-cold cardioplegia solution and the heart collapsed within the chest.

His heart stopped when there was no longer any reason to pump, no longer any life-blood to circulate. A heart can't beat, it seemed, without something nourishing to fill it. I thought again about Harvey, who in some sense stripped the heart of its metaphors when he found it was only a pump. Yes, I thought with a sense of loss, looking at the limp muscle that beat moments ago. It was just a pump. And yet, this pump was enough for the child who would soon accept the donated organ. And it would always carry this fervent message from the parents who relinquished it: please take this gift, so suffused with our hopes and dreams and yet, in the end, simply a cord of muscle that we hope will beat for decades to come, sustaining the life of the one you love and transcending the body of the one whom we loved.

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