Quick guide

Free will

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What is free will? Free will is the idea that we make choices and have thoughts independent of anything remotely resembling a physical process. Free will is the close cousin to the idea of the soul — the concept that 'you', your thoughts and feelings, derive from an entity that is separate and distinct from the physical mechanisms that make up your body. From this perspective, your choices are not caused by physical events, but instead emerge wholly formed from somewhere indescribable and outside the purview of physical descriptions. This implies that free will cannot have evolved by natural selection, as that would place it directly in a stream of causally connected physical events. Consequently, the idea of free will is not even in principle within reach of scientific description.

If free will is not a useful scientific concept, then how can we address the biological substrates of choice? Instead of getting hung up on the semantics of defining free will, modern biological approaches to the problem of choice have directed their efforts toward understanding how nervous systems: (1) frame the finite choices available; (2) value the choices; and (3) choose an option based on those valuations. This is a very economic rendering of the problem, but the problem of choice for biologically evolved creatures is exactly an economic problem. Viewed this way, it's easy to see why 'free' choice is an unconstructive way to conceptualize the way humans choose. Real-world creatures operate on finite energetic resources and so they are never free to choose from an infinite reserve of possibilities. Moreover, even among the finite choices available, some choices are much better than others. Imagine the creature that, upon detecting a fierce predator, has a nervous system that chooses to run straight at the predator. This kind of mechanism doesn't last very long in the real world, and therefore we don't see good examples of such 'non-escape' behavior in creatures today.

Much of the best biological work in decision-making has been carried out in bacteria and insects because the genetics of these organisms is better understood and they provide the most physically accessible nervous systems. With the advent of modern imaging and neurophysiological techniques, however, decision-making by human and non-human primates has become a bustling area in the early stages of development. This work has focused largely on the important problem of valuation — the way that nervous systems assign differential value to available behavioral options. And it's this valuation step that appears to provide human decision-makers with an especially developed capacity — the ability to use abstract ideas to control our behavior. It is this capacity that resembles, but is not equivalent to, the older ideas about will.

Is there any mechanism or capacity in the human nervous system that resembles will? It's well known that abstract ideas can commandeer a person's behavior and often in odd ways. For example, humans routinely go on hunger strikes based on political ideas and can inhibit their drive to take in food — even to the point of death. The capacity for abstractions to veto survival instincts can be seemingly arbitrary and the abstraction does even not have to possess any basis in reality. One need only remember the 1997 mass suicide of the Heaven's Gate cult based on the idea that there was a spaceship hiding in the tail of the comet Hale-Bopp waiting to take believers 'to the next level'.

The ability to make choices inconsistent with survival is a potent ability to choose and one that brings potential physical danger to its possessor.

Does the capacity to make choices inconsistent with survival demonstrate that humans possess something like free choice? The dramatic examples above appear on the surface to resemble the old philosophical idea of free will — choosing a course of action against all biological imperatives. As we illustrated above, humans do not possess the traditional notion of free choice; however, they do possess a capacity for flexible choice. One way to understand this flexibility is by hypothesizing that these 'pathologies' of choice represent extremes in the normal human capacity for cognitive innovation — the ability to form and pursue novel ideas not directly related to immediate survival needs.

As biological creatures, we are intimately tied to the demands for our survival — breathing, eating, procreating, avoiding trouble, and so on. Cognitive innovation requires (at least) a kind of timeout from these demands, as well as elevation of the value assigned to the innovation, that is, the new idea or behavior. To pursue some idea not directly related to survival our brains would need mechanisms to turn down the importance of survival needs and turn up the value of the idea. This hypothesis makes an important point. Our choices never were free, but they remain rather flexible and they do so by allowing abstractions to be able to commandeer our attention and behavior — at least temporarily. This capacity provides one direct conduit from the culture that we build and further allows this culture to couple rather tightly to our behavior. This is a biological process that we do not understand, but it exposes all sorts of important ramifications for our treasured social institutions — schools, laws, government, and so on.

Are there practical ways in which valuation mechanisms change a human's capacity to choose? Yes. Consider drug addiction (choose any drug). Modern biological approaches to drug addiction have attacked the problem at numerous levels of description. We now understand a great deal about the neuroanatomy, neurophysiology, and molecular interactions that are influenced by drugs of abuse. Over the last 15 years, however, computational descriptions of reward processing systems have added another perspective to this literature. These models have identified reward-prediction error signals encoded in fluctuations in dopaminergic neuron activity in the midbrain. Midbrain dopamine systems are hijacked or perturbed by every drug of abuse and these systems are intimately tied to the way that the mammalian nervous system values choices available to it.

Such models portray addiction as valuation disease, where the nervous system over-values cues associated with drugs or drug-taking. However, there is a point here: the addicted

nervous system is choosing highly valued options, a rational maneuver; but the valuation on the drug-associated cues is pathologically high. So loosely, one might see this as a diminished will — a lowered capacity to choose behavioral options not leading to drugs, but resulting from bad valuations of cues associated with drugs. The mechanisms that make the choice conditioned on the valuation appear intact. So these approaches to addiction have given us a new way to conceptualize what might have been lazily labeled a 'lack of will' on the part of the addict. These computational models are growing in sophistication each year and are now being used to direct physiology experiments, neuroimaging experiments, and the assessment of various therapies in this domain.

There are other conditions that can also dramatically affect a person's capacity to carry out normal value-dependent choice. Strokes, traumatic brain injury, coma, and various metabolic conditions can all influence one's capacity to value behavioral acts and mental states, and so will compromise the ability to navigate a 'normal' life. Often family members or even the courts must step in and decide whether to turn off life support machinery, yet without any good understanding of what functions might need to recover for this 'normal life' to ensue nor how they might recover nor how to make measurements related to these unidentified functions. So we have a lot to learn in this domain, but this is exactly the arena where the best science needs to inform the decision-makers. I say inform here because even once the mechanistic answers are clearer, we will still have to choose what to do with them.

How can I find out more?

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Obituary

Gunther Stent

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Gunther Stent, pioneer molecular biologist and neurobiologist, died in Haverford, Pennsylvania (USA) on June 12, 2008, at the age of 84. He died in part as a result of bacterial pneumonia, an irony he might have appreciated as a founding member of the group of scientists who exploited *Escherichia coli* and bacteriophages to decipher the mechanisms of heredity at the molecular level, beginning in the 1940s.

Through his close intellectual, scientific and personal interactions with the principals of early molecular biology, his teaching, textbooks, critical essays and historical accounts, his philosophical lectures and writings, and, to a lesser extent, his own experiments, Stent helped establish the modern discipline of molecular biology. In the late 1960s, concluding that the major 'paradoxes' of this field had been resolved, he changed scientific directions, not once but twice, taking up first neurobiology and then the development of the leech. Among his numerous honors were his election to the American Philosophical Society, the American Academy of Arts and Sciences, and the National Academy of Sciences. Not bad for a Jewish refugee who later recounted his childhood humiliation at being excluded from the Hitler Youth in Nazi Germany.

Born Günter Siegmund Stensch on March 24, 1924 in Berlin, he was the youngest of three children. His parents, Georg and Elizabeth, were affluent, non-observant and thoroughly assimilated Jews. The family name was changed to Stent upon emigration from Germany; Gunther anglicized his given name at the same time. His father's business manufactured and sold bronze statuary and lighting fixtures. Following his mother's struggle with depression and suicide when he was 10, Gunther was raised by his sister Claire. When the Nazis banned Jews from the public school system in 1935, Gunther was enrolled in a Jewish school (Private Waldschule Kaliski) which during its short existence produced three future Berkeley professors and other distinguished graduates. As the rising tide of anti-Semitism forced his family to flee, Gunther and his stepmother were the last of the family to go, making a narrow escape on foot into Belgium on New Year's Eve 1938, after a harrowing encounter with German border guards.

While his father and brother remained in England, Gunther came alone to America in March, 1940 to live in Chicago with his sister Claire and her husband Robert Hines. Having graduated from Hyde Park School in 1942 after only two years study, Gunther attended the University of Illinois, Champaign-Urbana on scholarship, supplemented by work as a soda jerk/short order cook at the local drugstore and by reduced membership fees at the Tau Epsilon Phi fraternity, which needed to raise its academic standing. His fascination with railroads and steam engines led to an honors degree in physical chemistry; a second major in philosophy reflected his passionate, life-long interest in that field. Gunther graduated in December 1944 after only 29 months as an undergraduate and became an American citizen in 1945.

At the encouragement of his undergraduate thesis mentor, Frederick Wall, Gunther enrolled in graduate school at Illinois and became involved in the synthetic rubber research program conducted for the War Development Board. The task was to find ways to correct for the elastic defects in synthetic rubber caused by the heterogeneity in the chain length of the molecules. Gunther published two papers but his efforts were largely superceded by the end of the war. He defended his dissertation in 1948 at the age of 24.

He interrupted his graduate study to serve eight months (1946–1947) in the Interallied Field Information Agency, Technical (FIAT), nominally assessing scientific and technical innovations in German industry. Gunther found this effort useless, but it did generate free time and the credentials to travel in postwar Germany. During this time he returned to Berlin, revisited his childhood sites, began proceedings to reclaim family property confiscated by the Nazis, skied and fulfilled his teenage aspiration of romancing blond, German women. It is this last activity that occupies most of his autobiography, '*Nazis, Women, and Molecular Biology*' (1998), which seems written in large as an apology to these women.

Like several other pioneers of molecular biology, including Seymour