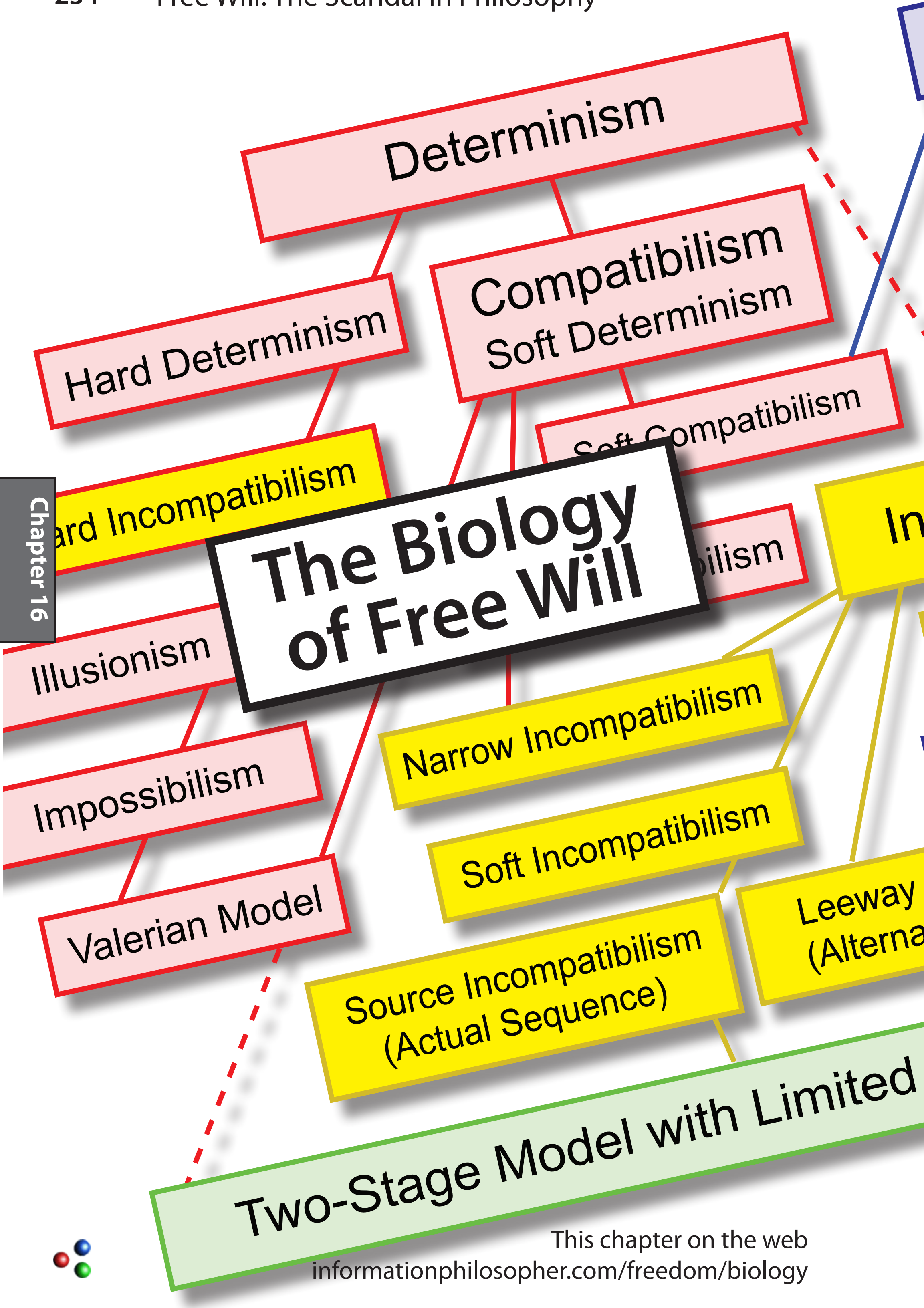

This chapter on the web
informationphilosopher.com/freedom/biology

The Biology of Free Will

Perhaps physics now puts no limits on human freedom, but what about biology? Each of us gets a significant amount of genetic information from our parents, which at least predisposes us to certain behaviors that have evolved to improve our reproductive success, sexual behavior, for example.

Are we completely "determined" by a combination of our biological nature and the social nurture of our environmental conditioning? Is biology itself all a causal process that is simply unfolding from a distant past that contained all the information about the one possible biological future?

Information biology says no. While the stability of biological systems is extraordinary, and while their error-free performance of vital functions over many-year lifetimes is astonishing, their dependence on randomness is clear. Biological laws, like physical laws, are only **adequately determined**, statistical laws.

At the atomic and molecular level, biological processes are stochastic, depending on thermal and quantal **noise** to deliver the "just-in-time" parts needed by assembly lines for the basic structural elements of life, such as the amino acids needed by the ribosome factories to assemble proteins.

So our question is how the typical structures of the brain have evolved to deal with microscopic, atomic level, noise. Do they simply ignore it because they are adequately determined large objects, or might they have remained sensitive to the noise because it provides some benefits?

We can expect that if quantum noise, or even ordinary thermal noise, offered benefits that contribute to reproductive success, there would have been evolutionary pressure to take advantage of the noise.

Many biologists argue that quantum-level processes are just too small to be important, too small for the relatively macroscopic biological apparatus to even notice. But consider this evidence to the contrary.

Proof that our sensory organs have evolved until they are working at or near quantum limits is evidenced by the eye's ability to detect a single photon (a quantum of light energy), and the nose's ability to smell a single molecule.

Biology provides many examples of ergodic creative processes following a trial-and-error model. They harness chance as a possibility generator, followed by an adequately determined selection mechanism with implicit information-value criteria.

Darwinian evolution was the first and greatest example of a two-stage creative process, random variation followed by critical selection. Darwin's example inspired William James to propose the original two-stage model of free will.

Here I will briefly consider some other such processes that are analogous to the two-stage **Cogito** model for the human mind.

Creativity in the Immune System

Consider the great problem faced by the immune system. It stands ready to develop antibodies to attack an invading antigen at any moment, with no advance knowledge of what the antigen may be. In information terms, it needs to discover some part of the antigen that is unique. Its method is not unlike Poincaré's two-stage method of solving a mathematical problem. First put together lots of random combinations, then subject them to tests.

Biological information is stored in the "genetic code," the sequence of genes along a chromosome in our DNA. "Sequencing" the DNA establishes the exact arrangement of nucleotides that code for specific proteins/enzymes. All the advances in molecular genetics are based on this sequencing ability.

The white blood cells have evolved a powerful strategy to discover unique information in the antigen. What they have done is evolve a "re-sequencing" capability. Using the same gene splicing techniques that biologists have now developed to insert characteristics from one organism into another, the white blood cells have a very-high-speed process that shuffles genes around at random. They cut genes out of one location and splice them in at random in other locations. This combinatorial diversity provides a variation in the gene pool very much like the Darwinian mutations that drive species evolution.

But the marvelous immune system gets even more random. It has a lower-level diversity generator that randomly scrambles the individual nucleotides at the junctions between genes. The splicing of genes is randomly done with errors that add or subtract nucleotides, creating what is called junctional diversity.

Bacterial Chemotaxis

Some of the smallest organisms are equipped with sensors and motion capability that let them make two-stage decisions about which way to go. They must move in the direction of nutrients and away from toxic chemicals. Some bacteria do this with tiny flagella that rotate in two directions. Flagella rotating clockwise cause the bacterium to tumble and face random new directions. Rotation of the flagella counter-clockwise drives the bacterium straight ahead. As the bacterium moves, receptors on the bacterium surface detect gradients of chemicals. When the gradient indicates "food ahead" or "toxic behind," the bacterium keeps going. If the gradients are not promising, the bacterium reverses the flagella rotation direction, which makes it tumble again.

In Nature Magazine,[1] the German neurogeneticist Martin Heisenberg challenged the idea, popular in the recent psychology and philosophy literature,[2] that human free will is an illusion. Heisenberg suggested that a lot could be learned by looking at lower animals. We can see that they do not merely respond to stimuli mechanically, but originate actions. He said,

> "when it comes to understanding how we initiate behaviour, we can learn a lot by looking at animals. Although we do not credit animals with anything like the consciousness in humans, researchers have found that animal behaviour is not as involuntary as it may appear. The idea that animals act only in response to external stimuli has long been abandoned, and it is

1 Nature, vol. 459, 2009, p. 164

2 Cf. especially Wegner (2002)

> well established that they initiate behaviour on the basis of their internal states, as we do."

One of Heisenberg's examples was bacterial chemotaxis.

> "Evidence of randomly generated action — action that is distinct from reaction because it does not depend upon external stimuli — can be found in unicellular organisms. Take the way the bacterium Escherichia coli moves. It has a flagellum that can rotate around its longitudinal axis in either direction: one way drives the bacterium forward, the other causes it to tumble at random so that it ends up facing in a new direction ready for the next phase of forward motion. This 'random walk' can be modulated by sensory receptors, enabling the bacterium to find food and the right temperature." [3]

An Error Detection and Correction System?

Errors in protein synthesis are arguably quantal. If errors prevent proper folding, the chaperone functions as an information error detection and correction system. If it succeeds in helping the protein to fold, the protein is released, otherwise the chaperone will digest and destroy the malformed protein.

Here the quantal noise will destroy the protein if the error cannot be corrected. It is of course not as if a new protein is being generated analogous to the accidental variations that genetic mutations introduce to the gene pool.

But it is instructive as an example of a two-stage process nonetheless, in that microscopic indeterministic errors are repaired by macroscopic, adequately determined, systems

Neurotransmitter Release as a Noise Source

Since information flows across the synapses, randomness of release times for transmitter quanta may be a source of information noise in memory storage and recall. Neurotransmitter "quanta" are of course huge compared to atomic-level quantum processes - containing thousands of molecules.

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3 Nature, vol. 459, 2009, p. 165

John Eccles thought this to be a meaningful source of noise, that it could help the brain make undetermined decisions, but he did not have a coherent idea of the process, like the two-stage model of free will.

Four Levels of Selection

I propose that there have been four levels in the evolutionary development of free will. In all four levels, the source of the random generation of **alternative possibilities** in the first stage of my **two-stage model** is the same. It is the essential chaos and **noise** that is characteristic of information processes at the lower levels of any organism.

But in the second stage, I argue that new methods of selection of the best alternative possibility get added at the upper levels.

Instinctive Selection

At the lowest level, selection is instinctive. The selection criteria are transmitted genetically, shaped only by ancestral experiences.

Learned Selection

At the second level are animals whose past experiences guide their current choices. Selection criteria are acquired through experience, including instruction by parents and peers.

Predictive Selection

Third-level animals use their imagination and foresight to estimate the future consequences of their choices.

Reflective (Normative) Selection

At the highest level, selection is reflective and normative.[4] Conscious deliberation about community values influences the choice of behaviors.

4 Compare Christine Korsgaard's theory of normativity. Korsgaard (1996)