Reading Guide 10

Irreducible complexity

This week, we continue the discussion of complex adaptations, focusing on the idea of *irreducible complexity*. This term was coined by Michael Behe, who defined it as follows.

> Irreducible complexity is just a fancy phrase I use to mean a single system which is composed of several interacting parts, and where the removal of any one of the parts causes the system to cease functioning. [Behe, 1996]

It is widely used by modern proponents of the intelligent design movement to argue that evolution cannot account for the intricate engineering found in all organisms.

10.1 History of the idea

Although the term "irreducible complexity" is relatively new, the idea can be traced back to the 1st century AD. Early authors used it as support for the reality of God. The argument was first used to attack evolution by Gustave Cuvier in the early 19th century. As Cuvier put it,

> The entirety of an organic being forms a coordinated whole, a unique and closed system, in which the parts mutually correspond and work together in the same specific action through a reciprocal relationship. None of these parts can change without the others changing as well. [Cuvier, 1831, p. 59]

Cuvier's critique was influential in discouraging evolutionary thinking in the decades before 1859.

In 1859, Darwin observed that

> If it could be demonstrated that any complex organ existed, which could not possibly have been formed by numerous, successive, slight modifications, my theory would absolutely break down. [Darwin, 1859, p. 189]

This passage has often been quoted by modern proponents of irreducible complexity. But Darwin went on to explain why the argument is hard to implement, because a single function may be served by several organs, and a single organ may have several functions at the same time or at different times. This allows selection to construct organs that exhibit irreducible complexity. Darwin provided several examples; modern evolutionists have discovered others.

The idea has been used many times in the years since Darwin, especially with reference to the vertebrate eye. The first person to use the eye in this context seems to have been Charles Pritchard

[1866, appendix A], the schoolmaster who taught mathematics and botany to Darwin's sons. A few months later, Joseph John Murphy discussed the eye in similar terms and concluded as follows:

> Here is a considerable number of parts and connections, every one of which would be useless without all the rest, and every one of which, consequently, pre-supposes all the rest. ... Mere spontaneous variation, and the preservation and transmission to descendants of favourable variations, with indefinite improvement on these through successive ages, will never account for the origin of the complex perfection of such an organ as the eye. [Murphy, 1866, cols. 2–3]

Murphy is arguing here that eyes are irreducibly complex and therefore cannot evolve by natural selection.

10.2 Behe [1996]: Evidence for intelligent design from biochemistry

1. What is "irreducible complexity?" How does it function as an argument against evolution?
2. Compare and contrast Behe's argument with those of Pritchard [1866], Murphy [1866], and Dewar [1931, pp. 83–84].
3. Behe argues that complexity at the molecular level is a greater challenge for evolution than complexity at a larger scale—that molecular machines are harder for evolution to explain than, say, the vertebrate eye. What are his reasons?
4. Summarize Behe's argument about the bacterial flagellum.
5. Summarize his argument about blood clotting.
6. Did Darwin [1872, pp. 146–148, p. 165] have an adequate response to Behe?

Dawkins [1986, p. 38] describes the "argument from personal incredulity," which in philosophy is called the "argument from ignorance". In the debate about evolution, such arguments have the form "I can't imagine how such and such could have evolved; therefore it didn't." These arguments are notoriously weak, because they may reflect nothing more than a failure of imagination. For this reason, this argument is considered a fallacy in logic.

7. Is irreducible complexity an example of the argument from personal incredulity, or is there more to it? If so, what?

Fleeming Jenkin [1867] accused Darwin of using argument from personal incredulity:

> He [Darwin] cannot imagine why abnormal organs and widely diffused genera should vary more than others, unless his views be true; and he says he cannot account for the peculiarities of distribution in any way but one. It is perhaps hardly necessary to combat these arguments, and to show that our inability to account for certain phenomena, in any way but one, is no proof of the truth of the explanation given, but simply is a confession of our ignorance.

8. Are Darwin and Behe both guilty of the same logical fallacy? If not, why is one author less guilty than the other?

10.3 Adami [2006]: Reducible complexity

Vocabulary When one molecule binds preferentially to another, each is the **cognate ligand** of the other. When the effect of one allele depends on the allelic state at another locus, the two loci are said to exhibit **epistasis** or **epistatic interaction**.

The biology The hormone *cortisol* binds to the *glucorticoid receptor*. The hormone *aldosterone* binds to the *mineralocorticoid receptor*. These two receptors evolved by gene duplication from an ancestral *corticoid receptor*.

1. The two receptors evolved by gene duplication 450 million years ago. Why is this puzzling?
2. By comparing modern molecules, the authors inferred the sequence of the ancestral corticoid receptor. What were its properties?
3. Two mutations, L111Q and S106P, were needed to get from the ancestral receptor to the modern glucocorticoid receptor. Depending on which of these came first, the order of events was either L111Q→S106P or S106P→L111Q. Which of these is more likely, and why?
4. Is this lock-and-key system irreducibly complex? If not, how could one ever recognize irreducible complexity?

10.4 Miller [2004]: The flagellum unspun

1. Summarize Behe's case that the bacterial flagellum is irreducibly complex.
2. What is the type III secretory system, and how does it relate to the bacterial flagellum? How does it affect the argument that the flagellum is irreducibly complex?
3. What do you make of the counterargument claiming that there are now two irreducibly-complex systems to explain, the flagellum itself and the type III secretory system?
4. The other counterargument observes that the new data on the type-III secretory system still do not tell us how either system evolved. Respond to this criticism.

10.5 Miller [1999]: The evolution of vertebrate blood clotting

10.5.1 How blood clots

Fibrinogen ("clot-maker") is protein in blood plasma. Has a sticky portion, which is usually covered by small amino-acid chains with negative charge. These repel, preventing the sicky bits from sticking.

- Clots form when a protease (protein-cutting) enzyme, cuts off the negatively-charged chains and the fibrinogen molecules (now called fibrins) stick together.
- This protease, called "thrombin," is usually in an inactive form—prothrombin.

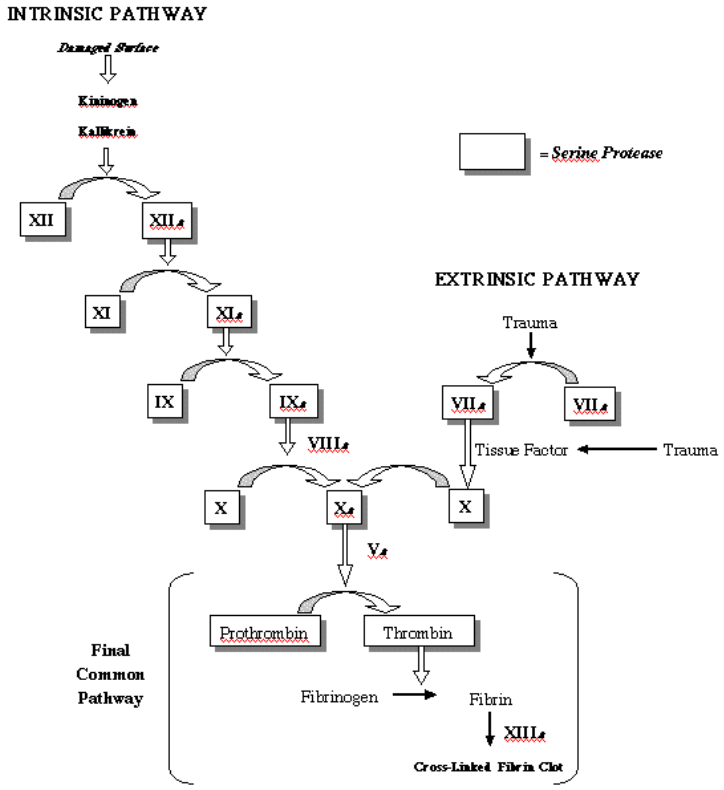

Figure 10.1: Blood clotting pathway [Miller, 1999].

- It must first be activated by another protease—Faxtor X.
- Factor X needs activation by either of two others—Factor VII and Factor IX.
- And so on, as shown in figure 10.1

Each step in the cascade amplifies clotting. As Miller [1999] puts it, "if a single active molecule of Factor XII could activate, say, 20 or 30 molecules of Factor XI, then each level of the cascade would multiply the effects of a starting signal. Put 5 or 6 steps in the cascade, and you've amplified a biochemical signal more than a million times."

1. Miller discusses what would have happened when a blood vessel broke in a small pre-vertebrate that lived 600 million years ago. Such an organism would not have had a clotting cascade. How would it have responded to an injured blood vessel? Why would this primitive system have been adequate?
2. What mutation(s) would be needed to establish a clotting system with a single step?
3. How could this evolve into a cascade with two steps?
4. What evidence supports the view that the clotting cascade evolved as Miller suggests?

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