I recently took a walk through the gardens of one of the magnificent residences of England, Chatsworth (look it up!). As I walked through the carefully tended and beautiful garden, it struck me that I was seeing a model through which we might view the Internet. Of course, at its most basic form, life is made of cells (think archaea, prokaryotes, and eukaryotes) that share a common DNA-based mechanism for reproduction and development. Other bio-active elements such as viruses and prions or other molecular fragments don’t have the apparatus they need for reproduction. Viruses accomplish the genetic interpretation of their DNA (or RNA) by hijacking cellular ribosomes that are part of the intracellular equipment of the three primary cell types.

One-celled life evolved into multicelled life (think sponges) and then into complex aggregations of multiple, specialized organs acting together to create new bioforms. The variety of living things is astonishing, given the apparent simplicity of the cells that comprise them. The Internet begins with pretty basic components that support the transmission of bits of information. These bits are organized into frames at the “link” layer, and within the frames are structured objects we call Internet packets that contain instructions on where they came from, where they’re going, what basic components they contain as payload, and what protocols or procedures should be activated on their arrival at a selected destination. TCP and UDP mediate the exchange of IP packets between source and destination devices connected to the Internet. These middle layers of the Internet protocol hierarchy function in some ways like DNA and the ribosomes that interpret the DNA to produce proteins. Of course, it’s more complex than that, because details such as DNA methylation have an effect on what is actually expressed to produce proteins. The Internet has background processes such as the Border Gateway Protocol and many intra-Autonomous System routing protocols as well as ARF and reverse ARP that are needed to effect packet flows.

Returning to the biological analogy, once the basic mechanisms of reproduction are established, the business of living must also be sustained. Cells must ingest fuel, extract energy, and excrete unneeded material. As we move from single cells to multicellular biological life forms, a kind of ecosystem emerges that’s even more pronounced in more complex, multi-organ creatures (including us!). Vascular systems are needed to deliver fuel and oxygen to cells and to remove waste products. Complex subsystems must cooperate to sustain life, and the same can be said for the Internet. A range of subsystems such as the DNS and routing systems must be in place to sustain the Internet.

The striking diversity of life and the emergent ecosystems that sustain it are matched in many ways by the striking diversity of systems and institutions needed to allow the Internet to operate, grow, and evolve. Before we even get to the World Wide Web’s emergent properties, we must consider the ecosystem of institutions that have emerged and that must cooperate for the Internet to function: ISPs, equipment makers, ICANN, the Regional Internet Registries, registries and registrars that operate the DNS, the Internet Society, the Internet Governance Forum, telecommunications operators, the IETF, regulatory agencies such as the US Federal Communications Commission and its counterparts elsewhere, and many more (sorry if I inadvertently left out your favorite element).

We can often find symbiosis in biology, and we see it even in ourselves (think bacteria in our digestive systems that not only participate

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in converting food into cellular fuel but also play a role in how our immune systems function). We could argue that a similar kind of symbiosis occurs among the many institutions that let the Internet continue to operate and evolve.

As we move toward higher layers of function in the Internet, we might see an analogy with the interaction of complex life forms in a competitive ecosystem. The food chain by analogy might be modeled by a wide range of hardware, software, and service institutions that support one another in a sort of hierarchy. The Web introduces another layer of protocols (approximately HTTP and HTML) that enable a wide range of applications and service provisioning, to say nothing of innovation applications and service institutions that support a wide range of hardware, software, and service institutions. Institutions build on these various layers of functionality, producing companies such as Google and Facebook that, themselves, enable more elaborate organizations and business models to form.

Ironically, we can even see an analogy between biological systems and the Internet as we look at various forms of cyber infections. We even use the same language — “virus” and “worm” — to refer to pathogens in the Internet (OK, “Trojan horse” doesn’t quite fit here).

Because certain costs are associated with creating and operating Internet infrastructure, I should also recognize the role that money and financial institutions and transactions play in the functioning of the Internet and its application space. Because institutions are made up of people, financial incentives play an important role in the Internet ecosystem.

Although I’ve barely been able to outline these hazy thoughts in a brief essay, I’m finding it helpful to think of the Internet as part of a very broad ecosystem in which there are many layers and many kinds of interactions that must be understood to appreciate its complexity and functionality. It seems to me that this perspective should also inform policy debates that are often bereft of either technical understanding or awareness of the complex ecosystem that has evolved and must be appreciated to inform policy making.

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