

Cancer is an Evolutionary Disease



Photo © Smithsonian Institution
Charles Darwin

Introduction

Among the great wonders of science are the interconnections revealed between seemingly unrelated aspects of nature. A four year adventure to some of the remotest and most desolate places of the world that began in 1826 upon HMS Beagle, provides the key to understanding and curing cancer. The word "cancer" is never mentioned in Darwin's book, [The Voyage of the Beagle](#). Yet the principle of evolution that Darwin discovered from his historic voyage is so fundamental and reveals such a profound truth of nature that it defines the requirements for the solutions to problems that Darwin never contemplated, including the specific cure of cancer.

Essential elements of evolution

Evolution is random variation and natural selection with "[survival of the fittest](#)" repeated over and over again. The mathematical and logical concepts that form the foundation of Darwin's Theory of Evolution are so simple and so obvious, that evolution in general, and "survival of the fittest" in particular, has been criticized as a logical tautology. Logical tautologies, like the statement, "red is red" are always true and tell us nothing.

Scientists accept Darwin's theory not because of its underlying logic, but because it accurately describes and explains the real world. By contrast, non-evolutionary models do not accurately reflect nature and are not tenable. Darwin's Theory of Evolution is among the best corroborated of all scientific theories and deserves to be considered a "principle of nature."

[Darwin's Theory of Evolution](#) has an almost mathematical quality. Evolution is not just a property of life.

The underlying principles of evolution apply generally to systems characterized by four properties:

- Random variation
- Reproduction
- Hereditary, or transmission of variations to offspring
- Selective pressure, which results in natural selection

Computer programs that apply these four simple rules provide the clearest demonstration of the generality of evolution. Evolution occurs. **Complex structures** and **solutions emerge** in the computer output that are increasingly fit and adapted to the selective conditions defined by the computer program. This is not surprising because information is at the heart of evolution. The principle of evolution is general. Cancer cell populations are no exception.

Tumor evolution is inevitable

It is easy to find systems and situations where the evolutionary nature of cancer is not noticeable. Studies with small numbers of cancer cells conducted for short time periods can appear to reveal a static, non-evolutionary picture of cancer. However, this does not correspond to the clinical situation that occurs in patients. Given a sufficient number of tumor cells and sufficient time, tumor evolution is inevitable.

The evidence that cancer is an evolutionary process is extensive and overwhelming. So much so, that non-evolutionary models of cancer are not tenable. This section will provide an overview of the evidence for tumor cell evolution and against non-evolutionary models of cancer. There is so much evidence that only representative examples can be presented in this web site.

The evidence that cancer is an evolutionary process is summarized below:

- I. Extensive genetic and epi-genetic alterations have been repeatedly observed in cancer cells within the same patient.
- II. Genetic and epi-genetic alterations have been shown to endow cells with survival and reproductive advantages and cause cancer.
- III. Natural selection has repeatedly been shown to occur in cancer cell populations as evidenced by the emergence of cancer cells with:
 - Novel mechanisms of malignancy
 - Increasingly aggressive behavior
 - Enhanced ability to metastasize
 - The ability to preferentially grow in different tissues

- The ability to evade the immune system
- The ability to evade apoptosis or programmed cell death
- Resistance to anticancer drugs
- Hormone and growth factor independence
- The ability to stimulate new blood vessel formation
- The ability to recruit normal cells to promote tissue invasion

Tumor cell evolution is the fundamental problem of cancer.

To understand cancer we must understand evolution. To cure or control cancer we must address the problem of tumor cell evolution.