same phenotype can result in more variation. I take up this concept of redundant representations with greater specificity when I discuss degeneracy as a source of robustness.

Mechanisms for Creating and Evolving Diverse Types

Mutation, drift, crossover, inversion, transfer, and representational diversity produce variation (differences within a type). I now turn to how a diversity of types emerges. In population biology, this is known as speciation. As discussed in the previous chapter, the distinction between variation within a species and across species isn't as clean as might be thought. It's clear that alligators differ from bluebirds, but dividing up all those orchids and warblers gets messy.

My discussion of the evolution and creation of type diversity relies on the *rugged landscape model* and its offspring, the *dancing landscapes model*. A rugged landscape is a graphical representation of a function defined over several variables in which the elevation of any type corresponds to its *payoff* or *value*. In biology, this *payoff* equals fitness, in economics, it equals profits or market share, and in the world of ideas, it could correspond to some combination of relevance and resonance. Thus, the payoff to a beetle may equal the number of viable offspring it produces. The payoff to magazine salesperson may be the number of subscriptions she sells, and the payoff to an academic may be the number of conference invitations.

The rugged landscape model assumes that fitness does not change. That would be true if fitness did not depend on features of other species. In reality, the value of size to one species usually depends on the size of other species in its ecosystem. This interdependence means that the fitness landscape for a species will fluctuate due to adaptations by other species. I will refer to these coupled rugged landscapes as dancing landscapes. Dancing landscapes capture co-evolutionary processes.

For now, what's important is that selection operates on both rugged and dancing landscapes. By that I mean that types that are not of sufficient elevation will not survive. Species that don't produce enough viable offspring, firms that don't make normal economic profits, and ideas that don't attract lots of followers die out. In order to understand what causes diversity, we first need to understand what survives selection.

In what follows, I describe six causes of diversity across types that build from this idea of landscapes: *isolation (different landscapes)*, *different peaks* on the same landscape, *coupled landscapes* which create diverse attractors, *local interactions*, *coordination* and *temporal variation*. These six causes are similar to what one would find in an introductory textbook in biology. These causes explain the diversity of products and ideas that exist in the world as well as the diversity of species in ecosystems. These are not meant to be exhaustive, but to capture the main causes.

Evolutionary theory distinguishes for modes of speciation: *geographic heterogeneity* (allopatry), *isolation of a small subpopulation* (peripatry), *divergent neighboring niches* (perapatry), and *diverse niches in common environment* (sympatry). Before proceeding further, I will attempt to make a distinction between a subspecies and a species. The difference is subtle. Consider a species that separates into two populations in disparate locations. If those two populations diverge, we might consider one a subspecies of the other. If the two species reunite, they may interbreed. They may not. If they do, their brief time apart would be considered just some youthful experimentation. If they do not interbreed, then they've become sympatric species, each carving out a distinct niche.

When I discuss speciation, I'm often talking about sub speciation – the creation of a subpopulation that differs. I gloss over whether that subspecies can interbreed with the original species. I'm accept this blurring of categories because I'm also covering ideas and products. They don't breed with one another, so they have no clear analog to species or subspecies.

Selection

In the ecological, economic, and ideological contexts, selection drives diversity. This might seem paradoxical. After all, selection drives out the unfit. It reduces variation and should work against the creation of diverse types. Without selection the mutation, recombination and the like would lead to runaway variation. Nevertheless, differences in the environment (either extant or created) can also enable selection to produce type diversity.

Replicator Dynamics

Before I can describe how selection produces diversity, I first show how selection reduces diversity. I'll do this using *replicator dynamics.* The *replicator equation* provides a convenient way to represent selection among a population of diverse types. For convenience, assume that time can be divided into discrete periods and that selection occurs between periods. The replicator equation gives the proportion of each type in the next period as a function of the type's payoff and its current proportion in the population. Types that earn above average payoffs increase in proportion, while types that earn below average payoffs decrease in proportion. The amount of increase or decrease depends on a type's proportion in the current population and on it's relative payoff.

The Replicator Equation

Let $(\pi_1, \pi_2, ..., \pi_N)$ denote the payoffs of N distinct types, and let $(p_1^t, p_2^t, ..., p_N^t)$ denote the types' proportions in the population at time t. Let $\bar{\pi}^t$ equal the mean payoff at time t:

$$\bar{\pi}^t = \sum_{i=1}^{N} p_i^t \pi_i$$

The **replicator equation** defines p_i^{t+1} as follows:

$$p_i^{t+1} = p_i^t \, \frac{\pi_i}{\bar{\pi}^t}$$

For the moment, assume that payoffs remain fixed over time, that no two types earn the same payoff, and that the initial population contains every type exists in strictly positive proportions. Given these three assumptions, replicator dynamics wipe out all but the type with the highest payoff. Hence, the well-worn phrase: survival of the fittest. The rate at which this occurs is geometric. That is, starting from equal proportions of types, after T periods, the proportion of each type is proportional to its fitness raised to the Tth power. We see this in the Repeated Replicator Equation below.

The Repeated Replicator Equation

Let $(\pi_1, \pi_2, ..., \pi_N)$ denote the payoffs of N distinct types. Assume that, initially, each type comprises $\frac{1}{N}$th of the population. After T applications of the replicator dynamic, the proportion of type i equals

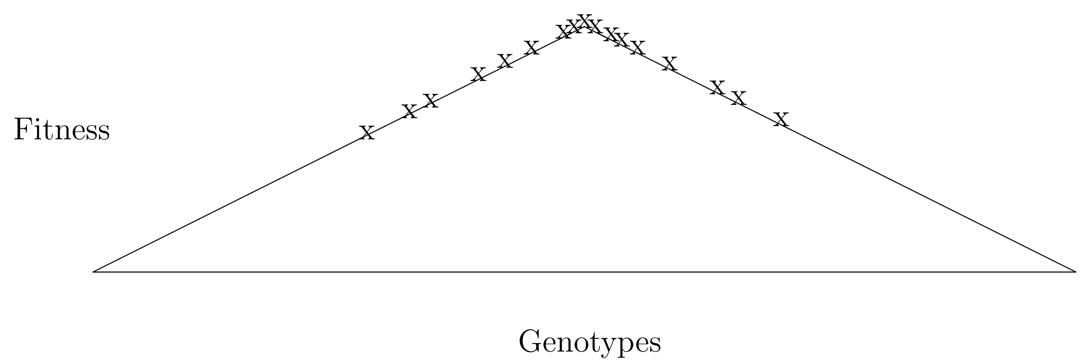
$$p_i^T = \frac{\pi_i^T}{\sum_{j=1}^{N} \pi_j^T}$$

Even though selection geometrically favors the more fit, it along with mutation is one of the main drivers of diversity. The question of how much of diversity is due to selection and how much is due to mutation is open to debate. The *neutral theory* of evolution (Kimura 1983) ascribes most of the weight to mutation and genetic drift, which I described previously. The debate hinges on whether most mutations are neutral, i.e. have no strong effect on selection, or if there exist enough mutations that confer sufficient selective advantage to prevent genetic drift.

Selection as Swarming a Peak

My analysis of selection borrows from ecology and from computer science. What I describe is a variant of biological mechanisms and a *genetic algorithm* (Holland 1975). A genetic algorithm begins with a population of entities. Each member of the population can be represented by a sequence of 0's and 1's. Think of this like DNA. For convenience, I assume a *fitness function* that assigns each of those strings a *fitness*. The fitness function maps the binary strings into the real numbers.[8]

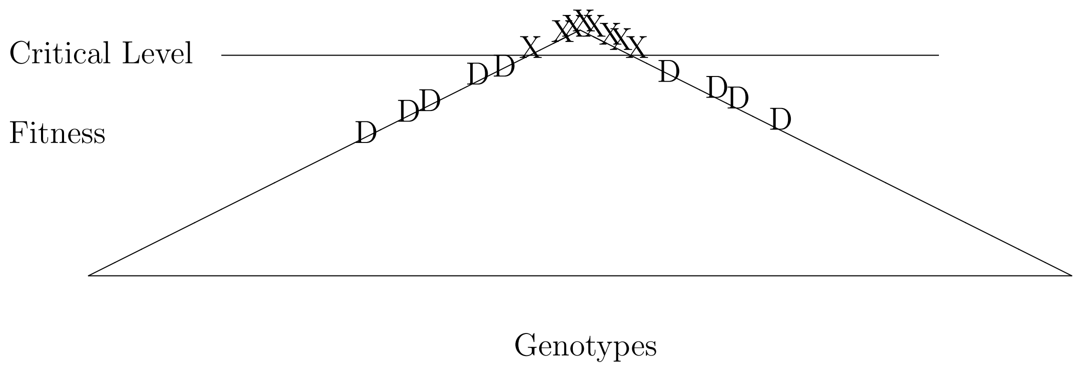
These assumptions create a *landscape*, where each entity is a point on a map and the entity's fitness is represented as an elevation. Landscapes are often categorized by the number of peaks that they have. A single peaked landscape such as the one shown below (also called a Mt Fuji landscape) poses little challenge to a selection operator. By that I mean, almost any rule for selecting better members of the population will locate the single peak on the landscape. Many landscapes are *rugged*, i.e. they have lots of peaks. In a few pages, we'll see how rugged landscapes produce diverse types.



Given a diverse population, selection drives out the unfit, or, alternatively, allows the fit to survive. Here, by *fitness*, I mean the standard biological representation of it – the ability to reproduce. For a species, we know what reproduction means. For an idea or product or restaurant to be reproduced it must be interesting or profitable enough to get copied, either by its inventor or by someone else. Goods and ideas must survive in the marketplace.

To capture survivability, I can emend the figure above and include a *critical level* of fitness – in effect, a water line. Any member of the species with fitness below the water line drowns (denoted by D). Any member with fitness above the water line survives and has the potential to reproduce.

[8]If we think of the entities as products, the 0's and 1's could denote the presence or absence, respectively, of attributes. Fitness would be profitability.



One final point on selection relates to those attributes not subject to selection. They'll be diverse. With no selection to stop genetic and ecological drift, differences can run wild. For example, some evidence shows that songbirds bred in captivity for beauty display greater variation in the songs they sing. This diversity arises because no selection takes place on the songs of these birds. Selection only operates on beauty (Lanier 2010). We can take this logic and construct some fun thought experiments. If all species lost the ability to see color, then color would no longer be subject to selective pressures. If after several thousand years, we could suddenly see color, we'd probably encounter a crazy multicolored reality.

Now that we have a basic understanding of selection and landscapes, we can explore how selection acts on populations to produce diversity.

Isolation (Different Landscapes)

The first explanation for how selection can produce type diversity relies on different landscapes. The version that I present here builds from the work of Ernst Mayr (2001). Suppose that we take two identical populations of dogs and place them in two distinct ecologies. The first population might live in a lovely river valley, and the second might live on a mountaintop. This separation could arise through a geologic event such as an earthquake or volcanic eruption, or it could have been human created. The figure below shows the average member of the population A and its fitness on each of the two landscapes.