The Balance of Nature

Blithering Genius

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1 The Mystical View of the Balance of Nature

People often talk about the balance of nature in mystical, quasi-religious terms. They believe that the order of nature is generated by some mysterious moral force that serves the interests of all life forms. They view nature as a kind of benevolent deity, the order of nature as intrinsically normative, and human intervention in nature as a kind of sin. They use terms such as “harmony” to describe how life forms fit together into ecosystems.

This view is wrong. The balance of nature is not an ideal state that is maintained by a mysterious process or agent. The balance of nature is simply the balance between reproduction and competition. Those two forces, acting on variation, generate the order of nature.

2 Organisms And Population Growth

Organisms can be categorized into types. A type is both a physical form and a way of life. For example, a species is a type of organism. Male and female are also types. How we divide up

organisms into types depends on what we are interested in. When we have defined the types that we are interested in, then we can talk about populations and population dynamics.

Each type that we define will have a population in an environment, and those populations may change over time or remain the same. Members are added to a population by reproduction or in-migration, and they are removed by death or out-migration. Populations grow when new members are added faster than they are removed. Populations shrink when members are removed faster than they are added. A balanced state is a balance between the addition and removal of organisms from a population. If net migration is zero, then it is simply a balance between birth and death.

All life forms have the capacity to reproduce to excess, because a life form without that ability couldn't arise by evolution. Thus, if all or most members of a population reproduce to their full capacity, the population will grow exponentially (multiplying every generation). That is a population explosion. To prevent a population from growing, something must prevent most organisms from reproducing to excess, usually by killing them before they have a chance to reproduce.

To give a simple example, suppose that a certain type of octopus lays 10,000 eggs. (Some octopus species lay more.) The life cycle of that octopus goes from fertilized egg to baby octopus to mature octopus to producing 10,000 fertilized eggs, followed by the death of the parent after the eggs hatch. If every new octopus were to live out the complete cycle, then the population would multiply by 5,000 in every generation.

Of course, in a very short time, that growth spiral would overwhelm the resources of the entire universe, let alone the resources of a coral reef. For the population of that type to be stable, the complete life cycle can only replicate itself once per individual or twice per female. On average, a complete life cycle should produce only one new complete life cycle. So, on average, 9,998 out of 10,000 baby octopuses must die without completing the life cycle. The cycle perpetuates itself, but most individuals don't complete the cycle. That's how nature works.

3 Life Competes For Resources

All types of life need resources to exist and reproduce. Resources can be divided into matter and energy, and both are finite. An ecosystem typically has a finite amount of different types of matter (even if it has flows of matter in and out of it), and a finite flow of energy that goes through it. Matter can be used over and over again, but energy is consumed in the process of converting it into work (2nd law of thermodynamics). To survive and reproduce, organisms must extract energy and matter from the environment, and because there is a finite amount of matter and a finite flow of energy, organisms must compete for those resources.

Resources are limited, but life has an unlimited capacity for growth. Thus, life is limited by resources. Since every ecosystem has a finite amount of matter and a finite flow of energy through it, it can only support a limited number of organisms of any type. So, as the population of any type of life increases, the competition between individuals of that type also increases, until competition balances reproduction.

4 Ecosystems And Population Dynamics

Different types of life use different resources. Plants get their energy from sunlight, herbivores get their energy from plants, carnivores get their energy from other animals, etc. Thus, plants tend

to compete with other plants, herbivores compete with other herbivores, and carnivores compete with other carnivores. Organisms of the same type depend on the same types of resources, and so organisms of the same type compete with each other. The most intense competition is usually between individuals of the same species. The same is true for the division between sexes. Males compete with other males for females, and vice versa.

In the abstract, population dynamics are very simple. As a population grows, competition tends to increase. Eventually competition stops the growth of the population by making it harder for members of the population to reproduce. In most cases, they are prevented from reproducing by premature death. The balanced state for a population is the state in which premature death removes the excess population in each generation. In the octopus example, it would be when 99.98% of baby octopuses die before reproducing. Thus, the balance of nature is attained when life is a desperate struggle to survive and reproduce, a struggle that has far more losers than winners.

The order of nature is the consequence of this process acting simultaneously on the populations of different types of life. Reproduction and competition generate a complex web of relationships: an ecosystem.

An ecosystem is a system of populations of different types of life. The organisms in an ecosystem interact. Some compete for the same resources. Some are resources (usually food) for others. Some provide niches in which others can live. Thus, the population of one type of life is affected by the populations of other types.

5 Interactions Between Types of Life In Ecosystems

The interactions between types can be positive or negative. For example, a predator population is positively affected by a prey population, while a prey population is usually negatively affected by a predator population. There is a negative interaction between types that use the same resources, such as trees in a forest competing for light and water. There can be a positive interaction between types as well, such as between humans and our livestock and crops. Finally and most importantly, there is the generally negative effect of a population on itself, due to competition between its members. The populations of different types of life in an ecosystem are determined by the total effect of all these interactions over time.

Not all interactions in nature are negative, but negative interactions are the ultimate factor that limits populations, organizes ecosystems, and drives evolution. Negative interactions remove the excess population generated by reproduction and most of the genetic information generated by mutation.

6 Stability And The Balance of Nature

The balance of nature is the state (of an ecosystem) in which the populations of different types are stable (or close to stable). This occurs by a simple mathematical process. Excess reproduction creates an upward pressure on populations, so they will increase until something stops them. The size of one population affects the conditions of life for other populations. If one population increases or decreases, that change will cause other populations to increase or decrease. Competition over finite resources means that populations cannot increase forever, and an increase in one population

is usually balanced by a decrease in another. The populations of different types of life will fluctuate until they all settle into a stable state, or perhaps oscillate around a stable state but never fully settle into it. Either way, the ecosystem tends toward a state in which every type of life just replaces its population without long-term increase or decrease. This occurs when life is equally difficult for all types.

The efficiency of an ecosystem in using energy and matter arises out of the competition for scarce resources. The complex order of an ecosystem, often described as "the harmony of nature", is created and maintained by the struggle for existence.

7 Instability In Nature

Life is easy only when an ecosystem is out of balance. For example, consider a landscape after a forest fire. Suddenly there is no competition for light, and so the landscape is quickly colonized by new plants. The colonizers reproduce to excess, and their offspring are able to survive in much greater numbers than their parents. There is a population explosion due to the surplus of available energy (sunlight). The population explosion of new plants creates the conditions for a population explosion of animals that feed on plants, which creates the conditions for a population explosion of animals that feed on animals, and so on. Life forms fill up the ecosystem, and as they do so, they create new niches, which are then filled by other types of life. The process takes a long time, but eventually a stable ecosystem emerges again: a climax forest in which the populations of different types of life are stable. In the stable state, there are no under-utilized resources, and thus no population explosions.

It is not only physical events, such as forest fires, that throw ecosystems out of balance. The introduction of a new type of life can also push an ecosystem out of a balanced state. New types of life can enter an ecosystem by migration or mutation. Suppose that a new type of life enters an ecosystem, and the new type can extract a surplus of resources from the existing system. The population of the new type will then increase at the expense of other types until it reaches an equilibrium. At first, individuals of the new type will compete mostly with individuals of other types, but as the population of the new type grows at the expense of other types, individuals of the new type will compete more often with each other. Eventually the population of the new type will stop growing and the ecosystem will be in a new equilibrium.

8 Selective Equilibriums

The fancy term for the balance of nature is an "evolutionarily stable state", or "ESS". It should be called a "selective equilibrium", because it is stable with respect to selection, not evolution. A selective equilibrium is similar to a Nash equilibrium in game theory. In a Nash equilibrium, each player is playing the best strategy given the strategies of the other players. In a selective equilibrium, the population of each type is stable given the populations of all types.

Selective stability is a natural norm. Ecosystems tend toward selective equilibria, and then stay in that state or close to it, until the environment is perturbed or a new type of life enters the ecosystem by mutation or migration. This stability is not magical or mysterious. It happens because the system keeps changing until it is stable. It's not much different from how a marble in a bowl will eventually settle down at the bottom.

9 Conclusion

The balance of nature is not an ideal state designed to serve the needs of organisms. There is nothing magical or mysterious about how different types of life fit together into a complex system. It is not cooperation between the species in an ecosystem. It is not a paradise. The balance of nature is just a stable state in which reproduction is balanced by competition.