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Configurationalism

An Alternative to and Generalization of Darwinism

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Abstract

In this thesis I present Configurationalism as an *alternative to* and *generalization of* Darwinism. Darwinism is the interpretative framework used to make sense of biological evolution in terms of concepts such as *fitness*, *natural selection* and *adaptation*. Darwinism is built upon two core ideas. The first idea is that of *biological design* which, among other things, includes the idea that individuals *adapt* to their environment.¹ The second idea is that of the *struggle for existence* which is understood in terms of individuals competing for survival and reproduction.

Configurationalism is an alternative to Darwinism, because it rejects the idea that individuals adapt to their environment. It might be scientific fact that individuals change over time in the presence of certain environmental factors, but it is metaphysical speculation to infer from such change that the individuals involved are ‘adapting to their environment’. Configurationalism is a generalization of Darwinism, because it generalizes the struggle for existence from being about individuals competing for survival and reproduction to patterns competing for volumetric occupation.²

One of the reasons one might prefer Configurationalism over Darwinism as an interpretative framework for biological evolution, is because it is better able to accommodate for the evolution of non-reproducing entities like, for example, giant fungi and tree groves. It is also better able to accommodate for the evolution of entities which do not have a fundamental unit of heredity, but instead create offspring in the image of their physical constitution at the time of creation. Moreover, the evolution of, for example, sterile worker and soldier castes in eu-social species such as ants is also made more intelligible, as the fact that the worker and soldier ants are not actively reproducing does not prevent one from assigning them a fitness in terms of their increase in volumetric occupation as a group.

Such a change in understanding of both biological design and the struggle for existence has important consequences for how one makes sense of biological evolution. Whereas Darwinism, generally speaking, understands natural selection

¹Biological design is an umbrella term I use to refer to the underlying conception of biological evolution from which concepts such as adaptation, biological function and ecological fitness derive.

²A pattern should be understood as a class of entities. In other words, it is not the individuals that instantiate a pattern that struggle against each other, but the patterns that these individuals realize.

in terms of the differential survival and reproduction of individuals, Configurationalism understands natural selection in terms of the differential spatial expansion and temporal propagation of patterns. Similarly, whereas Darwinism understands fitness in terms of an individual's ability to survive and reproduce, Configurationalism understands fitness in terms of the rate at which a pattern increases in volumetric occupation.

This change in the understanding of biological evolution has, in turn, important consequences for how one understands the nature of selection, the unit of selection and the nature of fitness. From the Configurationalist perspective, natural selection is a *form* of evolution and not a *cause* of evolution. Furthermore, two distinct forms of natural selection exist: system-level natural selection, defined in terms of the shape of an evolutionary trajectory, and ensemble-level natural selection, defined in terms of the representatives of an evolutionary trajectory. This distinction helps clarify the difference between natural selection as *process* and as *outcome*.

Furthermore, from the Configurationalist perspective there is no unit of selection, not in terms of a unit that benefits from evolution nor in terms of a unit that natural selection acts on. Patterns, and therefore traits, increase in representation 'for their own sake' and not for the sake of the survival and reproduction of the trait carrier they are attached to. Similarly, fitness should be understood as being a *growth rate* which reflects the rate at which a trait increases in representation and not a *disposition* which reflects the ability of an individual to survive and reproduce.

A concrete example of how such a re-interpretation of biological evolution might change the way we understand the evolution of certain phenomena is the evolution of altruism. Whereas the evolution of altruism is often presented as a conflict between selection acting at the level of the individual, often referred to as *within* group selection, and selection acting at the level of the group, often referred to as *between* group selection, Configurationalism unifies these two selection process by showing that there is *short-term* selection for selfishness but *long-term* selection for altruism. Thus, instead of understanding the evolution of altruism as a conflict between selection acting on different levels of biological organization, the evolution of altruism is understood in terms of the different timescales over which traits are expected to increase in representation.

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There are, undoubtedly, many more people that, in one way or another, contributed to the ideas presented in this master thesis. I cannot possible name (or recall) each and everyone of you, but if we ever had the pleasure of conversing about biological evolution, than consider this paragraph dedicated to thanking you too.

Preface

This thesis is the result of over ten years of thinking about biological evolution. Over these years I have worked out my thoughts about many more topics than I can possibly address in a single master thesis. This thesis, therefore, can only give a taste of the full gamut of my ideas. There were many instances where I would have loved to elaborate on this or that topic, but decided against doing so, because I feared it would turn my thesis into an long-winded and fragmented collection of ideas as opposed to a concise, focused and coherent whole.

If I were, for example, to explore my ideas about patterns in perception and their relation to Kant's ideas about the apriority of space and time as forms of intuition, I would soon be writing a second master thesis before finishing the first. There are, therefore, many instances where I have decided it be better to say nothing than to write some short and cryptic passage which confuses rather than enlightens.

It should also be noted that the writing in this thesis is a compromise between Sam the humble explorer of ideas with his nuanced opinions and Sam the bold synthesizer of ideas with his grand narratives. This is an important point, because even though I genuinely believe the ideas presented in this thesis are of immense importance for furthering our scientific understanding of biological evolution, I am also keenly aware that, in the grand scheme of things, they are but a small contribution to the body of scientific knowledge.

This juxtaposition between Sam the explorer and Sam the synthesizer is reflected in the epigraphs at the beginning of each chapter. Given that the introduction and conclusion are written more boldly and opinionated, their epigraphs contrast this attitude with that of Sam the explorer. Similarly, given that the chapters in the body of the text are written more nuanced and matter of fact, their epigraphs contrast this attitude with that of Sam the synthesizer.

Sam Hafkenscheid
Amsterdam, September 26, 2022

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A prayer before study

Creator of all things, true Source of light and wisdom, lofty origin of all being, graciously let a ray of your brilliance penetrate into the darkness of my understanding and take from me the double darkness in which I have been born, an obscurity of both sin and ignorance. Give me a sharp sense of understanding, a retentive memory, and the ability to grasp things correctly and fundamentally. Grant me the talent of being exact in my explanations, and the ability to express myself with thoroughness and charm. Point out the beginning, direct the progress, and help in completion; through Christ our Lord. Amen

St. Thomas Aquinas

Chapter 1

Introduction

“Who is this that obscures my plans with words without knowledge? Brace yourself like a man; I will question you, and you shall answer me. Where were you when I laid the earth’s foundation? Tell me, if you understand. Who marked off its dimensions? Surely you know! Who stretched a measuring line across it? On what were its footings set, or who laid its cornerstone?”

– The LORD, *Job 38:2-7*

1.1 The planetary fungus: A short story

Imagine a far away future in which humanity has conquered the galaxy. You are a scientist specialized in Darwinian evolutionary theory and a special request has been made for your expertise to study a new species of giant fungi on a far away planet. The first thing you notice arriving on this distant planet is the fact it is almost completely covered by the fungus. It is your job to study the evolutionary history of the fungus and explain how it became the dominant species on the planet. The first thing you do is dive into the records, as decades of dedicated researches have already logged and studied most of the fungus its physiology and interaction with the surrounding environment.

1.1.1 Diving through the records

The first thing you learn about the planetary fungus is that it is considered a single organism by standard biological procedures and definitions.¹ Researchers preceding you speculate that the fungus you see today is the same as the proto-fungus that made this planet its home millions of years ago. Unlike most species known to humanity, however, this fungus does not appear to age nor reproduce, instead it appears to expand indefinitely.²

¹See [1] for more on biological individuality

²This story is *fictionally*, but not unrealistic. Fungi are among the largest and longest living organisms on earth, the largest fungus known lives in Oregon and is ten square kilometers

Interestingly enough, even though the fungus is considered a single organism, it does have a patchwork structure to it in which local patches of the fungus have adapted to the different environments found on the planet. In colder climates, for example, the local patches produce special proteins to prevent freezing and in environments with heavy rainfall the local patches have special organs to drain the water falling on the surface of the fungus. The relationship between these patches and the fungus as a whole is similar to the relationship between one's limbs and one's body.

The second thing you learn about the planetary fungus is that in controlled lab environments it was found that the fungus has a special adaptive mechanism which researchers conjecture allowed the fungus to expand unimpeded by the differing environmental conditions on the planet. Research conducted on samples of the fungus suggest that when the fungus encounters a new environment this adaptive mechanism gets triggered by the disproportionate and premature death of cells in or near the edge of a new environment the fungus is not well adapted to. Once the mechanism gets triggered the rate of expansion increases and epigenetic triggers try out different patch profiles that have historically proven successful (e.g. a patch profile generally adapted to colder climates).³

Once a suitable patch profile has been found (signaled by the reduced cell death near the edge) or when no such patch profile has been found after all stored patch profiles have been tested, the fungus moves to the second phase of the adaptive processes in which the copying fidelity of the hereditary information in the cells in the expanding part of the fungus decreases and the mutation rate increases. This second phase researchers conjecture is meant to either refine a stored patch profile or find a new patch profile all together.

Furthermore researchers also observed that in lab tests the fungus would, in general, only cease its expansion when encountering itself again. This situation was observed when two samples of the fungus were released in the same test environment and enough sustenance was provided for continued expansion. Once the samples made contact they simply merged and no physical traces remained of the fact they once were two distinct samples of the same fungus. Any differences in stored patch profiles was observed to be synchronized between the two samples through the process of horizontal DNA transfer.⁴

The third thing you learn is that researchers found that some of the patches form 'clusters' in which the patches co-evolved in such a manner that they became dependent on the exchange of resources with other patches to maintain themselves in their current form. Some researchers, you read, described that the patches in these clusters operate in a similar manner to how the lungs, the heart and the stomach exchange resources to secure both their own survival and, in doing so, the survival of their partners.

in size and between two and eight thousand years old [2, 3]. They have also adapted to an incredible range of environments [4], being able to, for example, digest rocks [5] and harvest ionizing radiation [6].

³See [7] for more on epigenetic triggers

⁴See [8] for more on horizontal DNA transfer.

1.1.2 A Darwinian nuisance

Having finished your tour through the archives you realize there is a problem. Traditionally speaking the process of adaptation is understood in terms of the differential survival and reproduction of individuals based on their trait profile which, over time, leads to individuals becoming more adapted to their environment than their direct predecessors.⁵ In the case of the fungus, however, there is only one individual of the whole species and, furthermore, this one individual does not actively engage in any form of reproduction.

One solution you consider is treating the planetary fungus as a population of cells undergoing differential survival and reproduction. Though this approach solves the problem of having only a single individual, as opposed to a population of individuals, it also raises a new problem, because the adaptations observed at the level of the fungus as a whole do not reduce to some simple combination of adaptations observed at the level of its cells. Thinking of the fungus as a population of cells in which the individual cells compete among each other, you realize, fails to accurately capture the biological complexities associated with the organismal nature of the fungus: cells, and even whole patches, specialize and cooperate to perform specific tasks and functions which benefit the fungus as a whole; they are not maximizing their own reproductive success at the cost of other cells in the fungus.

You realize that this planetary fungus requires a new understanding of what it means to evolve: a new way of making sense of the process of adaptation that does not require individuals to actively reproduce. A way that accommodates individuals who grow in size and, in doing so, adapt to the environments they encounter.

1.1.3 Reinterpreting the struggle for existence

After prolonged thinking you realize that survival and reproduction are just two sides of the same coin. Survival helps retain volume already conquered while reproduction helps conquer new volume. Within any environment the volume available is finite, because the environment itself is finite. If one species increases in its volumetric occupation, another species necessarily has less volume available to occupy. Occupying volume, like gathering resources, is a zero-sum game.

From this perspective survival and reproduction are but means to an end: increased volumetric occupation. Thus, even though most organisms produce offspring and, in doing so, increase the volume occupied by their species, it is a perfectly legitimate evolutionary strategy for a single individual of a single species to grow in size and diversify its organs and cell composition and, in doing so, increase the volumetric occupation of both itself and its species.⁶ There

⁵Direct predecessors should be understood in the sense that, as long as the environment stays stable between generations, one can meaningfully compare their degree of adeptness to the environment. If one goes back far in time enough, however, to where the past environment no longer resembles the current environment, comparing the degree of adeptness of past and current generations becomes meaningless.

⁶The use of the word species is heuristic. In reality it increases the volume occupied by trait carriers with a similar trait profile. In other words, the representation of a certain class of trait carriers with a certain trait profile (i.e. a pattern) increases. Trait carriers and trait

even is an intuitive generalization of fitness from this perspective. Whereas ordinarily one defines fitness in terms of the number of offspring produced, one can now define it in terms of the increase in volume occupied.

1.1.4 Implications and advantages

One immediate advantage of this volume-based approach is that the planetary fungus no longer seems so problematic. Even though one cannot analyze its evolutionary history in terms of the differential survival and reproduction of different variations of fungi belonging to the same species, one can analyze its evolutionary history in terms of the differential rate of volumetric increase of the different trait profiles of the different local patches in different environmental conditions.

There are more advantages, however, as you realize that this volume-based approach also more easily makes sense of sterile worker and soldier castes in eusocial insects such as ants, termites, bees and wasps [9, 10, 11, 12, 13, 14]. As long as one variation of worker increases more rapidly in volume than another variation of worker, it does not matter, from the perspective of evolution itself, whether or not this increase in volume was achieved through reproduction, growth or, as is the case for sterile workers, through external production.⁷

Another advantage is that, from this perspective, traits evolve for the benefit of the pattern and not the individual. Thus, even if individuals with trait profile A are less survivable and produce less offspring than individuals with trait profile B, they can still be selected for. Consider, for example, the situation in which individuals with trait profile A live, on average, for 60 days and produce 70 offspring in total, while individuals with trait profile B live, on average, 80 days and produce 80 offspring. If one were to naively assess fitness, based on an individual's ability to survive and reproduce, one might conclude that organisms with trait profile B are fitter than organisms with trait profile A. If, however, one looks at the fitness of the trait profile itself (i.e. the pattern), one must conclude that trait profile A is fitter than trait profile B, for trait profile A increases in representation at a rate of 1.17 organisms per day, while trait profile B only increases at a rate of 1 organism per day.

Thus, even though individuals with trait profile A are, from the perspective of individual fitness, less fit than individuals with trait profile B, it is also true that, over time, a population consisting of an equal number of individuals with trait profile A and with trait profile B will *evolve* such that the number of organisms with trait profile A will increase in relative representation, while the

profiles should be understood in a very general sense: A DNA molecule is a trait carrier, but so is a car. The traits of a DNA molecule might be expressed in terms of specific sequences of nucleobases, while the traits of a car might be expressed in terms of its color, horse power, number of seats, etc.

⁷One might think this situation is unique, but it all depends on perspective. Males require females to reproduce and females require males to reproduce. Consider this externalized reproduction a special case in which one type of organism requires another type of organism to reproduce, except now the other organism carries all the hereditary information for the other. One might object that males and females belong to the same species, but species are but artificial labels that have no bearing on empirical fact. It is equally possible to define male and female as distinct species which require each other to procreate, as such a redefinition has no empirical ramifications.

number of organisms with trait profile B will decrease in relative representation. This paradoxical situation is made insightful by realizing that it is not the individuals, but the patterns realized by those individuals, which vie for representation through volumetric occupation.

Last but not least, if one were to ever encounter a species in which individuals *constructed* their offspring in the image of their own physical constitution, one would not be able to describe the evolution of such a species in terms of hereditary units like ‘genes’, because the individual as a whole is the hereditary unit in such a scenario. Imagine, for example, a population of robots which engage in resource gathering in order to make physical copies of themselves. Instead of reproducing based on some blueprint they scan their physical constitution and then 3D print their offspring atom by atom based on that scan. Suppose the printer is entirely accurate to the scan, but the scan sometimes miss-scans parts of the robot. Any miss-scan resulting in a better ability to gather resources would, then, naturally lead to a process of natural selection, even though there is no ‘fundamental hereditary unit’ other than the individual robots themselves. Even physical damage sustained during the process of gathering resources would be transmitted (but then also quickly selected against). From the perspective of the modern synthesis, such a form of evolution would prove difficult to comprehend, but from this new perspective it simply does not matter what the ‘fundamental unit’ is that propagates in evolution. As long as the pattern propagates as a whole, it need not be reduced to the propagation of some smaller or more fundamental sub-pattern.

1.2 Configurationalism: Core concepts and ideas

The story of the planetary fungus is meant to illustrate that there are some phenomena, be they real or imaginary, which, even though they appear to exhibit a process of adaptation, fail to be easily comprehensible from the perspective of Darwinism. Whereas Darwinism makes sense of evolution in terms of the differential survival and reproduction of individuals, Configurationalism makes sense of evolution in terms of the differential spatial expansion and temporal propagation of patterns. Configurationalism derives its name from the fact that the trait spaces used to describe the evolution of trait carriers in chapter 5 derive from the *configuration spaces* used in chapter 4 to describe the evolution of patterns more generally.

Configurationalism, like Darwinism, provides an interpretative framework which allows the evolutionary biologist to make sense of biological evolution. It distinguishes itself from Darwinism in two fundamental ways, however. First, it rejects the idea that biological design is real and, therefore, requires a scientific explanation in terms of how nature ‘produced’ said design.⁸ Second, it generalizes the struggle for existence from being about individuals competing for survival and reproduction to being about patterns competing for volumetric

⁸Biological design is an umbrella term I use to refer to the underlying conception of biological evolution from which concepts such as adaptation, biological function and ecological fitness derive. Understanding the rejection of biological design in terms of a rejection of the idea that individuals *adapt* to their environment is, for all intents and purposes, close enough. In chapter 3 the relation between Darwinism and biological design, especially in the context of Paley and Hume, is discussed in more detail.

occupation. Thus, on the one hand it is an *alternative to* Darwinism while, on the other hand, it is also a *generalization of* Darwinism.

1.3 Goal of this thesis

The primary goal of this thesis is to (1) develop Configurational evolutionary theory, (2) contrast Configurational evolutionary theory with Darwinian evolutionary theory and (3) show the advantages of Configurational evolutionary theory when compared to Darwinian evolutionary theory.

The secondary goal of this thesis is to show how, from a Configurationalist perspective, one should understand (1) the nature of selection, (2) the unit of selection and (3) the nature of fitness. In particular it will be argued that natural selection should be understood as a *form* of evolution and not a *cause* of evolution; and that fitness should be understood as *growth rate* which reflects the rate of volumetric increase of a pattern and not a *disposition* which reflects an individual's ability to survive and reproduce.

Questions about the unit of selection often arise in the context of 'for whose benefit a particular trait evolved' or 'who the ultimate beneficiaries are of the evolutionary process'. Given that Configurationism rejects the legitimacy of such questions, it also rejects the idea that there is a meaningful or objective answer to the question 'what is the unit of selection'? Configurationism does, however, have something to say about the unit of accumulation and the gene-centered view of evolution. Given that patterns propagate as a whole, Configurationism rejects the idea that there has to be some fundamental unit on which 'adaptations accumulate'. It rejects the idea that the evolution of a species can be understood solely in terms of an accumulation of genetic changes.

The Configurationalist's insistence to study the evolution of a pattern as a whole, instead of reducing the evolution of a pattern to one of its sub-patterns (e.g. not just focusing on genes when studying organisms), entails that, within the context of biological evolution, Configurationism considers it essential to account for the influence of, for example, inter-generationally transmitted environmental structures (e.g. constructed niches) and cultural practices (e.g. learned behaviors). Even though the inter-generational transmission of genetic material is an essential part of the spatial expansion and temporal propagation of most biological species, it is simply not possible to fully understand the evolution of a species if one only focuses on genetic differences: Fitness differences are what determine evolutionary outcomes and not all fitness differences reduce to genetic differences.⁹

⁹If, for example, you are born into a wealth family you get to benefit from the wealth acquired by your parents and their ancestors (e.g. their real estate and businesses) and, in your education, you get to benefit from the expertise and knowledge circulating within your local community. Even though the genes you received from your parents are an important factor in determining your societal success, it would be a terrible mistake to attribute the differences in societal success between you and others solely to the differences in the transmission of genes, without also accounting for the differences in the transmission of wealth and knowledge that accompany the transmission of genes.

1.4 Context and motivation

In this section I give three reasons that motivated me to develop a Configurationalist evolutionary theory. The first problem is that I believe most, though not all, Darwinian evolutionary explanations to be either *ad hoc*, confused or lazy. The second problem is that I believe natural selection cannot, in fact, explain away the (appearance) of design. Even at the time of Darwin, if one were a Newtonian physicist, one would have to wonder what explanatory role there would be left for natural selection if the evolution of matter is governed by the laws of physics and set in stone by the initial conditions of the universe. The third problem is that I believe Darwinism, if taken to be an accurate description of physical reality, introduces arbitrary and artificial distinctions between, for example, organisms and their environments, individuals and the groups they are part of, as well as biotic and abiotic forms of evolution.

1.4.1 Darwinian evolutionary explanations

One of the motivations for developing Configurationalism as an alternative to Darwinism is that, at times, Darwinian evolutionary explanations either feel *ad hoc*, *confused* or *lazy*. They feel *ad hoc* in the sense that the criteria for what constitutes a proper evolutionary explanation are rather loose. Gould and Lewontin, for example, criticized the adaptationist program for its uncritical belief that natural selection could explain the existence of each and every trait an organism had, resulting in speculative ‘just-so-stories’ instead of factual reconstructions of evolutionary history [15, 16, 17]. Moreover, they feel confused in the sense that, instead of elucidating the existence of a trait, they only beg more questions. Penn and Számadó, for example, criticized the confused nature of Zahavi’s Handicap Principle which turns “Darwinian logic upside down” [18, p. 274] in order to ‘explain’ the existence of sexual handicaps such as the peacock’s tail [19, 20, 21, 22, 23].

They feel lazy in the sense that they provide only half an explanation. In my study of creationist objections to Darwinian evolutionary theory, for example, I noticed that many of the popular evolutionary explanations for the existence of complex organs like the eye failed to account for the behavioral integration necessary to generate the differential survival and reproduction required for the process of natural selection to operate [24, 25, 26, 27, 28]. Most Darwinian evolutionary explanations restricted their evolutionary explanation to the eye’s optical abilities, without explaining (1) the origin of the first photoreceptor cells in organisms and (2) the way in which the eye integrated with the rest of the organism. A detailed account for the behavioral integration necessary to generate differential survival and reproduction, for example, would be much elucidating: seeing without reacting provides no evolutionary benefit. The academic literature on this topic also appears to mainly focus on the eye’s optical ability [29, 30, 31].¹⁰ Similarly, the academic literature on the evolution of lungs also appears to primarily focus on the evolutionary history and function of lungs [32, 33, 34, 35, 36].

¹⁰If you know of more thorough literature on the evolution of the eye which provides a detailed conceptual analysis of the evolution of the eye in terms of a sequence of incremental fitness advantages of intermediate forms which go beyond a mere analysis of increased optical ability, please get in contact with me.

The fact that it is acceptable for Darwinian evolutionary explanations to focus on the *function* of a trait is because traits are thought to benefit the organism *because* they perform a certain function. Hence, explaining the function equates to explaining the trait. There are multiple theories about biological function in the academic literature [37, 38, 39, 40, 41], but from the Configurationalist perspective the physical universe is ‘mere matter in motion’ and, even though biological function might have heuristic value in making sense of the relation between parts and wholes, it fundamentally cannot explain *why* a given trait evolved.¹¹

To elaborate on this latter point. Even though it is perfectly legitimate to make sense of the evolution of the heart in terms of how the heart pumps blood and, in doing so, transports resources through the body which keeps the body alive, one cannot claim this is the reason for why it evolved. From the perspective of the thermodynamic dissipation theory for the origin of life [42, 43, 44, 45, 46], for example, one might equally argue that the function of the heart is to dissipate heat and that that is the fundamental reason for why it evolved. Given that there is no objective way to assess what a trait’s ‘true evolutionary function’ is in terms of ‘why it evolved’, Configurationism claims one should refrain from providing speculative evolutionary explanations for a trait’s existence in terms of its current or past function.

1.4.2 Scientific reductionism

Given that modern evolutionary biology has large overlaps with other scientific disciplines such as physics and sociology (see figure 1.1 and figure 1.2), it becomes increasingly expedient to have an overarching framework, like Configurationism, that unites the disparate conceptual ontologies of physics, biology and sociology, especially when dealing with phenomena on the intersection of two disciplines.¹²

Such an overarching framework is useful when trying to make the transition from physics to biology and from biology to sociology as depicted in figure 1.2. Whereas a physicist might consider a molecule *nothing but* a collection of atoms subjected to the laws of physics, an evolutionary biologist might see a complex process of differential replication in which the fitter molecules are selected for. Similarly, whereas an evolutionary biologist might consider a population *nothing but* a collection of individuals exhibiting certain behaviors, a sociologist might see a complex network of social structures and institutions acting in their own best interest, even if at odds with the best interests of the individual or the society as a whole.

Especially the conceptual ontologies of classical Newtonian physics and Darwinian evolutionary biology seems difficult to combine.¹³ Whereas the classi-

¹¹To phrase this provocatively: there is no adaptation, only change.

¹²Given that the conceptual ontology of both physics and chemistry is virtually the same, I will treat chemistry as an extension of physics for the purposes of this thesis. See section 2.4 for more on conceptual ontologies.

¹³In principle the argument is much more general than a Darwinian conception of physical reality not being able to (easily) reduce to a Newtonian conception of physical reality. The reason I like to frame the problem in terms of Darwinism reducing to Newtonian mechanics is because (1) most people in academia are familiar with Newtonian mechanics and (2) New-

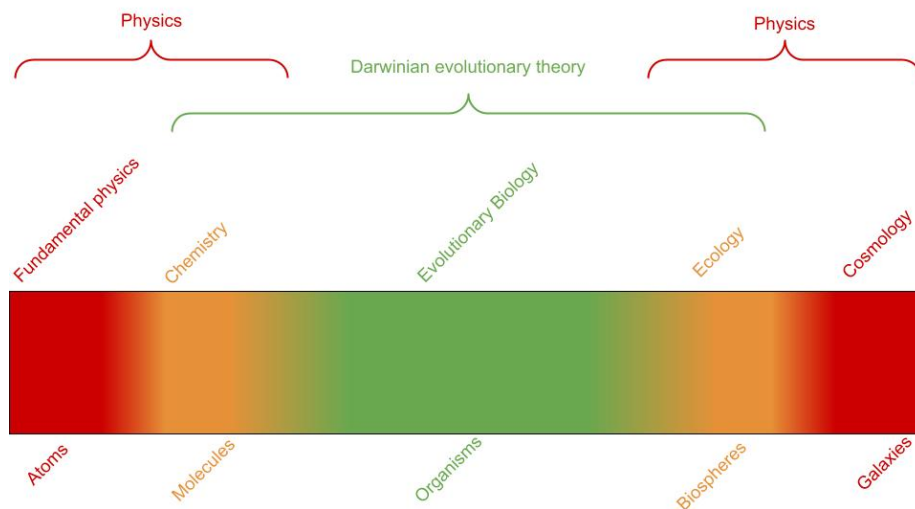


Figure 1.1: A visual representation of the different scales at which both physics and biology study the world.

cal Newtonian physicist views the evolution of the universe, including life, as nothing but the result of the initial conditions of the universe and the laws of physics, the Darwinian evolutionary biologist views the evolution of life as a special process guided by natural selection.¹⁴ But what explanatory role, in the fundamental sense, is left for natural selection if the universe is just matter in motion? As a higher-order theory Darwinian evolutionary theory might have heuristic value in making predictions and giving a sense of understanding, but when it comes to ultimate questions such as ‘why do organisms have the traits they have’ it seems much more expedient to use one’s best lower-order theories than one’s higher-order approximations.¹⁵ The question being whether natural selection can truly explain evolutionary outcomes, if those outcomes are, physically speaking, already set in stone.

tonian mechanics, even if not our most accurate or general physical theory about physical reality, does capture the central idea of the reducibility of evolutionary theory to physical theory ‘well enough’ that it is worth the trade-off in generality. See appendix A for a more general treatment in which Newtonian mechanics is conceived of as a form of dynamical bias within the Configurationalistic conception of physical reality.

¹⁴If the idea of an initial state of the universe bothers you, consider taking a past light cone whose size fully determines the temporal evolution of the solar system using relativistic physics. Furthermore, if the idea of determinism bothers you because ‘quantum’ consider that standard quantum theory is fully deterministic even if not determinate [47, 48].

¹⁵If you want to understand, for example, the motion of planets, a classical explanation in terms of gravity might have heuristic value, but if you *truly* want to understand the motion of planets, you must resort to a relativistic explanation in terms of the mass induced curvature of space.

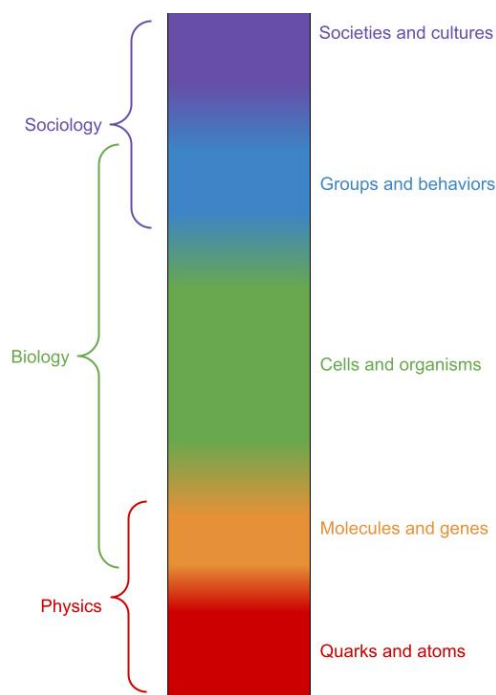


Figure 1.2: A visual representation of the overlap between physics, biology and sociology.

The situation of natural selection is, in this sense, similar to that of the second law of thermodynamics [49, 50, 51, 52]. Given that, in principle, there is only one evolution of the physical universe, and that each possible evolution is, in principle, unique, it seems that, even though the second law of thermodynamics might explain why, given our lack of knowledge about the exact initial state of a system one should expect certain macroscopic outcomes to manifest more often than others, it does not fundamentally explain the manifestation of said outcomes in the sense of explaining why the initial micro state happened to be the way it was.¹⁶

In principle, every microstate of a system is unique. Questions like ‘how come disorder increases’ have more to do with our perception of physical reality in terms of what we categorize as ‘disorder’ than physical reality itself. If one could only ‘see’ microstates, and lack the ability to ‘group them’ (making each microstate unique and unrelated to any of the other possible microstates) one would still be able to understand and use Newtonian physics, but thermodynamics would be incomprehensible. In other words, like with the second law of thermodynamics, is there genuine physical reality to natural selection, or is natural selection merely an ‘epistemic tool’ (as opposed to a physical process) to make sense of why we see certain traits more than others, rather than truly explain why certain traits are more abundant than others?¹⁷

¹⁶See [53] for more on the relation between Newtonian mechanics and thermodynamics.

¹⁷In chapter 5 and 6 it will be argued that system-level selection is a genuine physical process with causal powers, but that ensemble-level selection is nothing but an epistemic tool.

1.4.3 Arbitrary distinctions

Theories which make artificial and arbitrary distinctions, especially if the rules for discrimination are too vague to be applied consistently, are problematic. Rice, for example, writes that “selection acting at a particular level is not just a matter of semantics or computational convenience” [54, p. 298], which suggests there is an ontic distinction between individual and group selection. But if group selection exists and does not reduce to individual selection, how do we *objectively* determine whether the object of our study is an individual or a group? Why should some groups of cells be individuals (e.g. organisms) while others are not? And why, given that some groups of cells are individuals, should societies not be individuals (e.g. groups of organisms)?¹⁸

Similarly, the distinction between an organism and its environment also proves difficult to substantiate. Turner, for example, argues there is Richard Dawkin’s notion of an extended phenomena presents us with a paradox because “if the phenotype includes an organism’s environment, how then can the organism adapt to itself?” [56, p. 327]. If true, this means that one can no longer make a reliable distinction between genome and organism, replicator and vehicle, and structure and function [56, p. 328].

The distinction between biotic and abiotic evolution is also suspect. The distinction between an organism and a rock might be intuitive and clear, but the distinction starts to break down when studying, for example, the evolution of molecules or societies. But even at the level of the organism the distinction is not always clear. Bouchard, for example, writes that

If, as Turner argues, some physical structures (e.g. a mound) should be understood as an organ build by an organism, then we have to include nonbiological materials and structures in our definition of an evolving individual.¹⁹ [57, p. 567]

If true, the distinction between organisms and machines, for example, would be of heuristic value at the practical level, but utterly misguided at the fundamental level (cf. [58, 59, 60, 61, 62]). If the distinction between biotic and abiotic breaks down, man made machines and objects (e.g. cars and tables) also evolve under the selective pressures of their environments.²⁰

¹⁸The objection that societies, unlike organisms, do not have ‘well defined boundaries’ is problematic because many organism are holobionts [55] and, therefore, do not have well defined boundaries either. The main issue is that if groups of cells (i.e. organisms) can be thought of as having ‘agency’ and acting in self-interest, it is unclear why the idea that groups of organisms (i.e. societies) have ‘agency’ and ‘act in self-interest’ is problematic.

¹⁹If termite mounds, beaver dams, etc are ‘part of the organism’ this even further undermines the idea that societies are, somehow, from the Darwinian perspective, without ‘agency’ and ‘fundamentally different from organisms’.

²⁰The competition between tables, for example, can be thought of in terms of how well tables following different design philosophies can manipulate humans into buying and caring for them. Their reproductive cycle exploiting the basic need of human beings to have a place to ‘place items of the ground’ and forcing them to make tables, transmitting beneficial traits from one generation of table to the next. As Harari says: “We did not domesticate wheat. It domesticated us” [63].

1.5 Root of the problem

In section 1.4 three problems were presented which motivated me to write this thesis. The first problem was that of ad hoc, confused and lazy evolutionary explanations. The root of this problem, I think, is the idea that organisms adapt to their environment and that this process of adaptation can be explained in terms of the evolutionary function a trait performs. But, as Bouchard writes:

Fitness as design-problem solution is [...] famously unattractive to philosophers and biologists [because] it is not obvious how to individuate and count distinct design problems nor is it clear how to measure the degree to which they are solved by individual organisms. [57, p. 561]

In chapter 3 I will elaborate in greater detail how the idea that organisms adapt to their environment (e.g. the polar bear has adapted to a cold climate) and that traits evolve because they perform evolutionary functions (e.g. the fur of a polar bear evolved because it kept the polar bear warm) derive from Darwinism's deep commitment to the ontological reality of biological design.²¹

The issue is not that belief in the reality of 'biological design' is fundamentally wrong or even unproductive (in the context of polar bears it clearly is productive), but that there is a limit to how far commitment to this idea can be taken in the context of the scientific study of biological evolution without running into deep conceptual problems. Specifically, when it comes to the 'scientific legitimacy' of such an idea, it is important that it can be implemented *consistently*. How come organisms adapt to their environment, but environment not to their organisms? Did the evolution of planet earth entail that it adapted to the environment of the solar system? Is the function of stars in stellar systems to emit light in the visible spectrum and keep the planets around it in orbit? Furthermore, if we cannot, for example, identify the *relevant* functions of the traits of a species independently of and prior to the actual evolution of said species, we can only use biological design in an *ex post facto* manner to *make sense of* a given evolution, as opposed to *predict* said evolution (see section 2.5).

The second problem was the compatibility with physics. How to understand the concept of natural selection in a universe in which the initial conditions plus laws of physics fully determine any future state of affairs, including the evolution of those configurations of matter ordinarily identified as organisms. More specifically, how can an organism adapt to an environment, when the evolution of both the organism and its environment find their root in a common past cause. This problem does not have a 'quick fix', but the distinction between system-level and ensemble-level natural selection developed in chapters 4, 5 and 6 reconciles evolutionary biology with physics by showing that natural selection in terms of some 'guiding principle' is an epistemic tool for prediction as opposed to a physical process that causes.²²

²¹The fact that Darwinism is committed to the ontological reality of biological design *does not* entail that evolutionary biologists are. Newtonianism is committed to the ontological reality of gravity as a force, this does not mean that contemporary physicists actually believe gravity is a force. Some might say Darwinism has outgrown biological design, but I think it more accurate to say that evolutionary theory has outgrown Darwinism.

²²One might object that guiding principles are obviously a-causal, but the problem is much

The third problem was that of seemingly arbitrary distinctions between individuals and groups, individuals and their environment and biotic as opposed to abiotic configurations of matter and their evolution. The root of this problem, I think, is the idea that the struggle for existence should be understood in terms of individuals competing for survival and reproduction as opposed to patterns competing for volumetric occupation. By only recognizing *individuals* that survive and *reproduce* as subjected to natural selection, the scope of natural selection is severely limited due to the fact that individuals that do not reproduce are excluded and the difference between individuals, groups and environments is now ontically instantiated, since it is of paramount importance to establish whether a given configuration of matter is an individual, a group or part of the environment before making evolutionary predictions.

Configuralism, is an attempt to solve these problems by, on the one hand, dismissing the scientific legitimacy of biological design while, on the other hand, generalizing the struggle for existence. In doing so the aim is to develop an evolutionary theory which, on the one hand, is both insightful and non trivial in nature, but, on the other hand, fully compatible with the idea that, ultimately, ‘it just is what it is’ and that the evolution of each and every trait is, ultimately, only explained by the fact that the initial conditions of the universe and the laws of physics just ‘happen to be the way they are’.

1.6 Structure of this thesis

In chapter 2 *Preliminaries* I discuss the preliminaries necessary for properly understanding the rest of my thesis. In chapter 3 *Darwinism* I first discuss the historical context and conceptual structure of Darwinism and then hone in on its philosophical problems. In chapter 4 *Configuralism* I discuss the core ideas and basic principles of a Configuralistic approach to evolutionary research. In chapter 5 *Configural Evolutionary Theory* I develop Configural evolutionary theory in terms of the evolutionary trajectory of a population through trait space. In chapter 6 *Philosophical Reflections* I answer questions about the nature of selection, the unit of selection and the nature of fitness using the insights gained from chapter 4 and 5. In chapter 7 *Conclusion* I summarize the core arguments and philosophical implications presented in this thesis.

more subtle. Lagrangian mechanics, for example, makes use of variational principles which ‘guide particles to the right outcome’. Such a guiding principle is not necessarily epistemic in nature and, therefore, not necessarily without causal efficacy.

Chapter 2

Preliminaries

“I will recall you at a later point”

– Carl, *The Invoker*

This chapter discusses the differences between Darwinism, evolution, common ancestry and evolutionary theory. It also elaborates on the structure of scientific theories in terms of both conceptual ontologies as well as interpretative and empirical frameworks. It concludes by discussing the idea of added scientific value in the context of biological evolution, the difference between system-level and ensemble-level properties and reviews some of the ideas in the academic literature that are similar to the ideas presented in this thesis.

2.1 On the difference between Darwinism, evolution and common ancestry

The terms evolution, Darwinism and common ancestry are, unfortunately, often used interchangeably, which can lead to unnecessary conceptual confusion [64, 28]. This thesis does not use these terms interchangeably. Evolution, biological evolution to be more precise, is an *observed fact* and refers to the process in which the trait distribution associated with a population of trait carriers (e.g. DNA molecules and organisms) changes over time (i.e. evolves) [65, 66]. This change can, but does not have to be directional (i.e. in the direction of increased fitness or adaptation). Common ancestry, also referred to as common descent, is a *historical claim* about the past, based on the backwards extrapolation of evolutionary processes and trends observed in biological evolution today and corroborated by, for example, paleontology and comparative genomics [67, 68]. Darwinism, I will argue, is an *interpretative framework* which makes sense of biological evolution and, by extension, common ancestry in terms of biological design and the struggle for existence (cf. [69]).

One can compare the distinction between evolution, common ancestry and Darwinism with the distinction between classical mechanics, cosmology and Newtonian mechanics. Classical mechanics is a purely empirical framework only con-

taining the empirical relations between observations.¹ Cosmology is a backwards extrapolation of these empirical relations, based on observational constraints in the present, in order to reconstruct the (cosmological) past. Newtonian mechanics is an interpretative framework which makes sense of the empirical relations contained in classical mechanics in terms of point particles and forces. The interpretative nature of Newtonian mechanics is easier to highlight than that of Darwinism, because unlike Darwinism, Newtonian mechanics has viable alternatives like Lagrangian and Hamiltonian mechanics.²

2.2 On the difference between Darwinism and Darwinian evolutionary theory

This thesis presents a critique and generalization of Darwinism and, by extension, a critique and generalization of Darwinian evolutionary theory as a whole. Darwinian evolutionary theory and evolutionary theory, however, are not the same.³ One can think of evolutionary theory as an empirical framework and of Darwinian evolutionary theory as a ‘scientific theory’ which combines both the interpretative framework of Darwinism and the empirical framework of evolutionary theory to provide an overarching scientific research program in which meaningful, though not purely empirical, research can be conducted (cf. [70, 71]). Since most contemporary research in evolutionary biology is done using Darwinian evolutionary theory, and therefore formulated in a Darwinian vocabulary, one must be careful not to mistake my critique of the Darwinian part of Darwinian evolutionary theory with the evolutionary theory part of Darwinian evolutionary theory.⁴

2.3 On the difference between empirical and interpretative frameworks

Most scientific theories consist of two parts: an empirical and an interpretative part (see figure 2.1).⁵ The empirical part pertains to ‘what you actually see and do’ while the interpretative part pertains to ‘how you make sense of what you see and do’. The empirical part merely consists of the relations between initial and final conditions of sensory input mediated by behavioral output. In other words: An empirical framework merely captures the structure of our observations. It involves a basic degree of inference, extrapolation and induction, but makes no claims about how ‘reality truly is’ outside of our sensory

¹To be more precise: between sensory input and behavioral output. In other words, between ‘I see these digits on the display’ (sensory input), ‘I press these buttons on the machines’ (behavioral output) and ‘I now see different digits on the display’ (sensory input).

²Newtonian, Lagrangian and Hamiltonian mechanics are interpretative frameworks of the empirical framework called classical mechanics.

³See also figure 2.1 in section 2.3 for a visualization.

⁴This one of the reasons why I believe it more accurate to frame the evolution of evolutionary biology in terms of evolutionary theory outgrowing Darwinism, as opposed to Darwinism outgrowing biological design.

⁵This is how *I* conceive of scientific theories. Others might conceive of scientific theories from the perspective of, for example, a syntactic, semantic or pragmatic view [70].

experiences.⁶

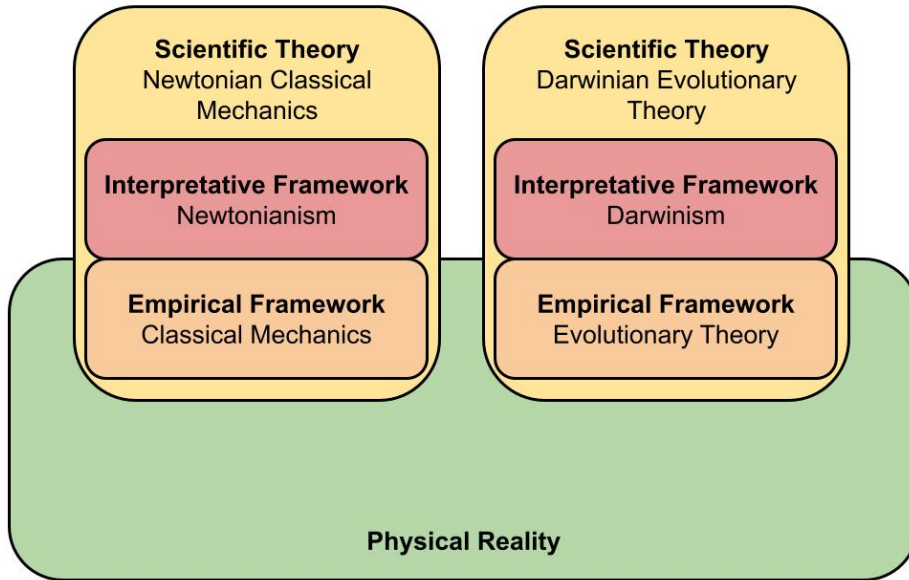


Figure 2.1: A visual representation of how scientific theories incorporate both empirical and interpretative elements in their description of physical reality. Newtonian classical mechanics is often abbreviated as Newtonian mechanics just as Darwinian evolutionary theory is abbreviated as Darwinian theory.

Most scientific theories, however, also consists of an interpretative part which ‘makes sense’ of the relations described by an empirical framework. The interpretative part usually consists of a conceptual model of reality (i.e. a conceptual ontology) from which the empirical relations contained in the empirical framework are either derived or through which those relations are made intelligible. The Darwinism part of Darwinian evolutionary theory, for example, makes the increase in representation of a certain trait intelligible in terms of how said trait benefited the individual in its evolutionary struggles.

Evolutionary theory, in principle, only concerns itself with empirical facts such as the relationship between the change over time in the representation of traits in a population in the presence of certain environmental factors. Darwinian evolutionary theory then makes changes in the representation of traits intelligible in terms of differential fitness values, selection coefficients and adaptive advantages, just as Newtonian mechanics makes changes in the relative position of particles intelligible in terms of forces and Lagrangian mechanics makes changes in the relative position of particles intelligible in terms of action.

⁶There is no reason to worry about theory-ladenness in an empirical framework, since there is no theory to begin with. Empirical reality is understood in terms of ‘if I see A and respond by doing X, Y, Z, I will see B, since in the past doing X, Y, Z after seeing A also yielded B in M out of N times of seeing A’ (c.f. [72]).

Distinguishing between a scientific theory's interpretative and empirical framework is usually not necessary. But when the empirical adequacy of an interpretative framework's conceptual ontology becomes suspect, for example due to an increase in the scope of its empirical framework, it becomes paramount to distinguish between criticism of established *facts* and criticism of the *interpretation* of said facts. Denying the conceptual cogency and empirical adequacy of Darwinism does not equate to rejecting evolutionary theory, just as rejecting Lagrangian mechanics in favor of Newtonian mechanics does not equate to rejecting classical mechanics.⁷

2.4 On the idea of a conceptual ontology

Most scientific theories are derived from a certain conceptualization of reality. Newtonian mechanics, for example, conceives of physical reality in terms of particles and forces. Such a conception of reality I will call a *conceptual ontology*. Whereas the purpose of an actual ontology is to represent reality as it truly is at its most fundamental level, a conceptual ontology merely provides a way to think of reality which, for all intents and purposes, is good enough. A Newtonian conception of reality, for example, can no longer figure as an actual ontology given our discovery of both quantum and relativistic phenomena. This does not mean, however, that a Newtonian conception of reality is completely wrong, it still is a productive mode of (scientific) thinking in many situations, nor that we cannot reasonably explore the philosophical implications of a Newtonian conception of reality if it were ontologically accurate, even if we do not actually believe it to be ontologically accurate.

Applying this line of reasoning to Darwinism, one might argue that the conceptual ontology of Darwinism is one of reproducing individuals engaged in the struggle for existence [73, 69]. The struggle for existence entails that individuals are conceived of in terms of 'struggles' such as trying to 'get food, have sex and avoid pain'. Darwin's explanatory value lies in the fact that, if an individual has a trait which proves ever so slightly beneficial in these struggles, that said individual is probably going to produce slightly more offspring and that, therefore, over time, beneficial traits will increase in representation within a population and, over sufficiently long timescales, a species more generally. In order for this process of natural selection (for beneficial traits) to work, it is further required that the trait profile of offspring strongly resembles the trait profile of parent (i.e. heredity) and that different individuals have different trait profiles (i.e. variation).

The power of this conception of biological reality, is that, for most sexually reproducing organisms this description is both insightful and predictive: If I am going to a cold climate I want a thick coat to keep me warm. It makes sense, therefore, that polar bears evolved 'a thick fur to keep them warm' in the Arctic environment. Darwinism, in this sense, is predicated on the idea that, due to natural selection, the traits and behaviors of organisms belonging to the same species are, in general, designed to fit the environments they inhabit (e.g. the

⁷One might reject Lagrangian mechanics, for example, because one believes the teleological implications of particles 'deciding where to go to minimize action' to be problematic, not because one believes Lagrangian mechanics to be empirical inadequate.

arctic) and the lives they live (e.g. being a hunter).⁸

The conceptual ontology of Configurationalism, on the other hand, is one in which the universe is conceived of as a giant spatiotemporal grid in which each tesseract has a *property when probed*. For the sake of simplicity and tractability, however, this thesis will conceive of these tesseracts as being populated by ‘atoms’, but see appendix A for a more detailed treatment of this conception. It is then shown how all material evolution, including biological evolution, can be understood in terms of the different rates at which patterns realize in perception (see appendix A.5 for more on patterns in perception). Concretely this will be done in chapters 4 and 5 using weighted configuration spaces and their corresponding trait spaces. Traits and trait carriers only appear as an emergent description of physical reality in Configurationalism and, while the different rates at which trait profiles increase and decrease in representation can be studied in relation to the environmental factors that correlate to such trends, these trends are not understood in terms of trait carriers adapting to their environment, traits performing functions or any other form of ‘design-language’. Even the idea that ‘patterns’ struggle for volumetric occupation is *explicitly* metaphorical in nature, as the interpretive value of Configurationalism’s conceptual ontology does not hinge on its reality.⁹

2.5 On the idea of added scientific value

An important concept throughout this thesis is the concept of *added scientific value*. The core idea behind added scientific value is that of conceptual parsimony: no need to include or incorporate ideas and practices into the body of science, if these ideas and practices do not add anything to our ability to actually do science [74]. If an idea, theory or hypothesis is beyond verifying, without any empirical consequences, making no predictions whatsoever, then there is no reason to include it into the body of science, even if, for some weird reason, it turns out to be ontologically accurate.¹⁰

Within the context of this thesis the idea of added scientific value finds two uses. The first use is in the context of evaluating whether Darwinism has any added scientific value. In particular one might wonder whether the lack of context transitivity of fitness values and selection coefficients poses a problem (see sections 3.5.3 and 6.3.1). Whereas a Newtonian mass and gravitational

⁸One might object that this is not how Darwinism is understood today, but what remains of Darwinism if both biological design (i.e. organisms adapting to their environment) and the struggle for existence (i.e. organisms actively struggling to achieve some evolutionary goal) are understood as nothing more than metaphors? What distinguishes Darwinian evolutionary theory from evolutionary theory if one removes all of Darwinism’s interpretative layers?

⁹Unlike Darwinism which understands the struggle for existence in terms of individuals competing for survival and reproduction, the Configurationalist understanding of the struggle for existence in terms patterns competing for volumetric occupation can be applied consistently without introducing arbitrary distinctions between, for example, individuals, groups and environments. As such, there is no empirical harm in conceiving of biological evolution in terms of patterns competing for volumetric occupation.

¹⁰Suppose, for example, that God revealed to the scientific community that He created absolutely undetectable winged pigs flying through the universe. Even if true, what are the scientist supposed to do with this knowledge other than conclude that, apparently, God has a weird sense of humor?

force easily translate between different experimental contexts, fitness values and selection coefficients do not, making them unsuitable for predictions outside of the context in which they were conceived.¹¹

The second use is in the context of whether natural selection is a cause of evolution (see section 6.1.2). Unless a cause has *physical instantiation* there is little to no point in incorporating it into our scientific theories (cf. [75, 76, 77, 78, 79]). In other words, if I claim that A is a cause of B and I cannot point you to anything in physical reality that A refers to, not even in principle, then there is no legitimate empirical content to the claim that A is a cause of B that you, as a scientist, can verify and, hence, me claiming that A is a cause of B has no added scientific value.¹²

Furthermore, if a cause cannot be identified with some element of physical reality *prior to* and *independently of* its effect, it also has no added scientific value.¹³ If the only way to identify natural selection as a cause of evolution is by its effect on evolution, it can never be used to make any predictions about evolution. It would be the equivalent of inferring the reality of leprechauns, without actually ever having seen a leprechaun, because some household items went missing and, apparently, it is common knowledge that leprechauns like to steal household items when we are not looking. At some point there is just nothing left to explore, research or manipulate except for an elaborate game of after the fact categorization.

2.6 System-level and ensemble-level properties

Configurationalism builds on the idea that a system can be described by a micro-state and a macro-state. A micro-state is a more exact description of a system than a macro-state. A macro-state description for a sequence of five coin flips might be 3H2T (three heads and two tails) while the corresponding micro-state description might be HHTHT (in that order). It is important to note two things. First, a macro-state can be realized by multiple micro-states: both HHTHT and HTHTH realize 3H2T. Second, there is, classically speaking, only one true micro-state evolution of a system.

A system-level property or phenomenon is a property or phenomenon at the level of the *individual* system. The number of heads in a particular sequence of coin flips or the average kinetic energy of a collection of particles is a system-level property. An ensemble-level property or phenomenon is a property or phenomena at the level of an *ensemble* of systems. The fact that there was only a one in thirty-two chance of obtaining the micro-state HTHTH when flipping

¹¹We can, for example, define and measure the ‘divinity’ d of a particle as the square root of its mass times its electric charge to the power of its acceleration ($d = \sqrt{me^a}$), but this quantity would, within the context of Newtonian mechanics, be of no scientific relevance. Just because something can be measured and named, does not mean it has scientific relevance.

¹²Even though empirical content is an important aspect of the idea of added scientific value, there is more added scientific value than mere empirical content. A new method of calculation or a reinterpretation of established facts might have, for example, added scientific if they speed up our ability make predictions or allow for a more intuitive understanding of results, even if there is no immediate increase in the empirical scope of our scientific theories.

¹³Prior to because otherwise it cannot be used for predictions, and independently of because otherwise it might be two effects with a common cause.

a coin is not a property of the HTHTH micro-state itself, but a property of that micro-state *in relation* to all the other micro-states the system might have taken. The concepts of system-level and ensemble-level properties and phenomenon will be used in section 5.2 to distinguish between system-level and ensemble-level natural selection.¹⁴

2.7 On similar ideas in the academic literature

The idea that biological design is problematic and that the struggle for existence is too restrictive is not, in and of itself, a new idea. The problem with the evolution of non-reproducing organisms, for example, has already been pointed out by [83, 57, 84, 85, 86]. Bouchard, for example, writes that:

To understand the evolution of some clonal organisms, colonial organisms and symbiotic communities, fitness in terms of offspring number will not take us very far. The success of these systems is in their overall survival, not in the reproduction of some of their members. [57, p. 568]

Even the idea of *temporal propagation* can, in some sense, be found in Bouchard's work in terms of persistence:

One fact remains clear. When we carefully examine some cases of biological evolution [...] we quickly realize that nature does not 'care' what is selected (parts or wholes) and so we might wish to replace the 'struggle for survival' by the 'struggle for persistence'. [57, p. 569]

Criticism of the ontic distinctions between individuals and groups based on multi-level selection theories also exist. Bourrat, for example, writes that:

The idea that there can be distinct processes of selection acting at each level of organisation is not as straightforward as its proponents claim it to be. There are good reasons to think that what looks like two distinct levels of selection is in fact one and the same process of selection operating over different environmental conditions, as a result of proxies of fitness being measured over different time scales. [87, p. 49]

Bourrat clearly recognizes that it is the same selection process that operates both at the level of the individual and the group and that their apparent difference is an artifact of the differences in timescale over which fitness is being measured. Bourrat's idea is very similar to the distinction between short-term and long-term selection in Configurationalism, which replaces the within and between group selection of Darwinian models of, for example, altruism (see sections 4.4.2 and 6.3.2).

What sets Configurationalism apart from this academic literature, however, is that it synthesizes all these ideas into a single overarching interpretative framework *from the ground up*. And, while authors like Bouchard point out the importance of differential persistence (i.e. temporal propagation) for natural

¹⁴My ideas about ensembles find their root in [80, 81, 82].

selection, they fail to account for the importance of differential spatial expansion.¹⁵

2.8 Chapter summary

Darwinism is an interpretative framework used to make sense of biological evolution, while evolutionary theory is an empirical framework used to describe biological evolution. Together they make the scientific theory referred to as Darwinian evolutionary theory which both describes and makes sense of biological evolution from a Darwinian perspective. Rejecting the Darwinian part of Darwinian evolutionary theory does not equate to rejecting evolutionary theory. This thesis argues in favor of Configurationalism and, by extension, Configurational evolutionary theory.

¹⁵It might also be worth pointing out that I read these papers after finishing the development of Configurationalism. In other words, even though I feel it appropriate to mention them as I can see their ideas are related to mine, it would be incorrect to characterize the development of Configurationalism as inspired by or based on their work.

Chapter 3

Darwinism

“You die as you lived: insipid and ignorant.”

– Carl, *The Invoker*

This chapter introduces Darwinism, Neo-Darwinism and the modern synthesis. It touches upon Darwinism’s historic relation to Paleyism and introduces the nature of selection, unit of selection and nature of fitness debates, which are three prominent topics within the philosophy of evolutionary biology [88]. In chapter 6 these topics are discussed in greater detail from the perspective of Configurationalism.

3.1 Historical context: Darwinism as a naturalistic rebuttal to Paleyism

Darwinism is not a single theory, rather, it is a set of concepts, principles and methodological maxims shared by a large family of theories and models about biological evolution, first formulated by Charles Darwin in his 1859 *On the Origin of Species* [73, 69].

In order to understand Darwinism, and in particular its focus on explaining biological design in terms of the adaptive advantage a trait provides in the struggle for existence, it is important to understand that Darwinism arose as a *naturalistic rebuttal* to Paleyism. Whereas William Paley argued in his 1802 *Natural Theology* that the appearance of design when studying the physical constitution of organisms indicated that there must have been a supernatural designer [89, 90, 91], Darwin argued that this appearance of design could instead be explained by his naturalistic theory of descent with modification by means of natural selection [39]. Allen and Neal, for example, write that:

Prior to Darwin, the best explanation for biological adaptation was the argument from design, most influentially presented in William Paley’s *Natural Theology* (Paley 1802): living things have the structure and behaviors that they do because they were designed for certain purposes by a benevolent Creator [...] Darwin’s theory provides

biology with the resources to resist this argument, offering a fully naturalized explanation for adaptation. [39, p. 3]

Notice how Darwinism is said to explain *biological adaptation* in a naturalistic manner (as opposed to a theological manner). In other words, Darwin accepted the idea that biological design was ‘real enough’ to warrant a scientific explanation. His disagreement with Paley was not about whether or not design was ‘real’, but rather, what constituted a proper explanation for said design. This is notably different from Configurationalism, which, being more Humean in nature, outright rejects the notion that the appearance of design is anything more than a subjective value judgment (c.f. [92]). In other words, it outright rejects the cogency of Paley’s argument: unless one can provide a systematic definition as to identify which physical entities ‘exhibit design’ (irrespective of whether or not they actually are designed), one is in no position to embark on a scientific inquiry in order to explain how the ‘designed nature’ of organisms came about.¹

Thus, even though, as Sober writes, “Darwin’s argument contradicted what was at the time *the* most influential argument for the existence of God - the argument from design” [94, p. 18], Darwin did not dispense with the idea of biological design itself. Rather, Darwin showed that no inference to a God was needed. Instead of ‘the designer’ being God, ‘the designer’ became nature herself which “scrutinising, throughout the world, every variation, even the slightest; rejecting that which is bad, preserving and adding up all that is good; silently and insensibly working, whenever and wherever opportunity offers, at the improvement of each organic being in relation to its organic and inorganic conditions of life.” [73, p. 76].

3.2 On the core ideas and concepts of Darwinism

3.2.1 Biological design

Both Darwin and Paley accepted that biological design was real and in need of an explanation, but where Paley thought the inference to a supernatural power appropriate, Darwin set out to find a natural process, still observable today, which could explain the appearance of design [69]. But how to understand biological design? And has contemporary Darwinism not outgrown Darwin’s rather vivid description of the process of adaptation?²

¹The reason I believe Paleyism so important, is because as Einstein wrote in his critique on the realism vs anti-realism debate: “I don’t feel very comfortable or at home with any of the “isms.” It always seemed to me as though such an ism was powerful only as long as it fed off the weakness of its counter-ism; once the latter is struck dead and it is alone on the deserted stage, it then proves to be just as weak-kneed” [93, p. 651]. Similarly I believe that Darwinism, without intelligent design or some other form of creationism to fend against, also appears unsteady on its feet if left alone on the scientific stage.

²This section is a little longer, as the idea that biological design is an essential ingredient of Darwinism is, I think, more contentious than the idea that the struggle for existence is an essential ingredient of Darwinism. Also, just to reiterate, saying that the reality of biological design is an essential conceptual ingredient of Darwinism’s conceptual ontology does not mean evolutionary biologists actually believe Darwinism’s conceptual ontology is an accurate representation of physical reality.

I use the concept of ‘biological design’ as an umbrella term to capture what I deem metaphysical speculation as to the nature of organisms. As such, I cannot provide an exact definition, but I can give examples to illustrate the type of language and thinking I associate with biological design. As mentioned before, I associate the concept of biological design with the idea that organisms *adapt* to their environment, that traits perform *functions*, that there are ‘design-problems’ the organism needs to ‘overcome’ and that there are entities which *benefit* from the process of evolution by natural selection. I think that understanding biological design as the cluster of ideas underlie the idea that organisms adapt to their environments is as close to a definition as I can give.

The idea of organism’s adapting to their environment, however, is rather abstract. Thus, to make the idea of biological design a little more tangible, consider Darwinian evolutionary theory as an attempt to explain ‘the designed and purposive nature’ of organisms’.³ Consider, for example, a polar bear living in the Arctic. Given that it is very cold, the polar bear has a thick fur to keep itself warm; given that the polar bear is a carnivore, it has sharp teeth and sharp claws to help it hunt and devour prey; given that the environment’s primary color is white, it has a white fur so that it blends in with the environment [95]. Moreover, a polar bear clearly moves with intention. It hunts prey for food, fights over mating rights, protects its offspring, etc. What it does not do, is aimlessly wander around until it dies of starvation.

Even in contemporary academic literature the idea of biological design, or at least its vocabulary, expresses itself in texts such as “a trait is an adaptation for performing a particular task [which] evolved because there was selection for the trait, where the trait’s selective advantage was due to it helping perform the task” [94, p. 196], “ x is fitter than y if and only if x ’s traits enable it to solve the ‘design problems’ set by the environment more fully than y ’s traits do” [96, p.2], “the entity that ultimately benefits from the selection process” [97, p. 24], “natural selection explains the appearance of design in the living world, and inclusive fitness theory explains what this design is for” [98, p. E1] and

Living things are well designed, in innumerable respects, for life in their natural environments. They have sensory systems to find their way around, feeding systems to catch and digest food, and nervous systems to coordinate their actions. The theory of evolution has a mechanical, scientific theory for adaptation: natural selection. [30, p. 67]

It is for good reason that Gould and Lewontin faulted “the adaptationist programme for its [...] unwillingness to consider alternatives to adaptive stories [and] for its reliance upon plausibility alone as a criterion for accepting speculative tales” [15, p. 581]. Even though they did not outright reject the idea of biological design, they did faulted it for the fact that it allowed “any sub-optimality of a part [to be] explained [away] as its contribution to the best possible design for the whole” [15, p. 585]. Lennox explains this appearance of ‘design-talk’ as follows:

The appearance of *teleology* is certainly present in Darwinian ex-

³I am borrowing vocabulary used by [59] to justify the idea that organisms and machines are (fundamentally?) different in nature.

planations, and has been since Darwin spoke of natural selection *working solely for the good* of each being. The appearance of teleology stems from the ease with which both evolutionary biology and common sense take it for granted that animals and plants have the adaptations they do *because* of some benefit or advantage to the organism provided by those adaptations. [69, p. 15]

But do we have empirical grounds to infer organisms genuinely *adapt* to their environments in the aforementioned sense? Or should we just take this claim as a metaphysical maxim underlying Darwinism? Lennox concludes that

Selection explanations are, then, a particular kind of teleological explanation, an explanation in which that for the sake of which a trait is possessed, its valuable consequence, accounts for the trait's differential perpetuation and maintenance in the population. [69, p. 15]

Notice, however, how traits evolve for 'their valuable consequences'. But valuable consequences for whom or what? Again, the idea that 'organism's benefit from their traits' is deeply ingrained in Darwinian thinking. None of this is to say that these authors necessarily believe biological design is real in some deep ontological sense, but, like with Darwin, I feel confident in saying that they consider it to be 'real enough' to do science with and about, just as physicists consider point particles to be 'real enough' to describe physical systems with. The problem, however, is that, like with point particles, there is a limit to the empirical scope and application of such a 'metaphor'.

In conclusion, Darwinism is predicated on the idea that biological design needs to be explained, and explaining biological design entails explaining why organisms look so incredible well designed, from an engineering perspective, to the environments they inhabit and the behaviors they engage in. Configurationalism is a rejection of this mode of thinking. The motivation is two fold. First, there is the Humean objection that one cannot objectively infer design (nor the appearance thereof) from physical constitution.⁴ Second, the concept itself fails to be cogent and cannot be applied consistently when applied to the full domain of biological evolutionary phenomena, unless one can prove that the distinctions discussed in section 1.4.3 are more than artifacts of our thinking.

3.2.2 Natural selection and the struggle for existence

Darwin introduces his idea of the struggle for existence as follows:

I should premise that I use the term Struggle for Existence in a large and metaphorical sense, including dependence of one being on another, and including (which is more important) not only the life of the individual, but success in leaving progeny. Two canine animals in a time of dearth, may be truly said to struggle with each other which shall get food and live. But a plant on the edge of a desert is said to struggle for life against the drought, though more properly

⁴I am reminded of Philo when he says that "Will you quarrel, Gentlemen, about the degrees, and enter into a controversy which admits not of any precise meaning, nor consequently of any determination?" [99, p. 86].

it should be said to be dependent on the moisture. A plant which annually produces a thousand seeds, of which on an average only one comes to maturity, may be more truly said to struggle with the plants of the same and other kinds which already clothe the ground. [73, p. 59-60]

Darwin then justifies the existence of a struggle for existence based on the following observation:

A struggle for existence inevitably follows from the high rate at which all organic beings tend to increase. Every being, which during its natural lifetime produces several eggs or seeds, must suffer destruction during some period of its life, and during some season or occasional year, otherwise, on the principle of geometrical increase, its numbers would quickly become so inordinately great that no country could support the product. Hence, as more individuals are produced than can possibly survive, there must in every case be a struggle for existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms; for in this case there can be no artificial increase of food, and no prudential restraint from marriage. Although some species may be now increasing, more or less rapidly, in numbers, all cannot do so, for the world would not hold them.⁵ [73, p. 60-61]

Darwin then reasoned that if certain traits provided an organism an advantage in the struggle for existence, however minor it may be, that those organisms are more likely to pass on their traits to the next generation. Darwin called this process of “preservation of favourable variations and the rejection of injurious variations” [73, p. 76] *natural selection*, also conjecturing that, given enough time, natural selection could explain the emergence of new species in terms of one species slowly changing into another species over time [73, p. 79].

This understanding of the struggle for existence in terms of ‘the life of the individual’ and its ‘success in leaving progeny’ still very much lays at the foundation of contemporary Darwinism. Ridley, for example, writes that “Organisms, therefore, in an ecological sense compete to survive and reproduce – both directly, for example by defending territories, and indirectly, for example by eating food that could otherwise be eaten by another individual.” [30, p. 73].

It is important to note that, even though the struggle for existence is a useful metaphor, this metaphor also derives from the idea that biological design is ‘real enough’ that it makes sense to treat organisms as agents actively striving after similar goals (e.g. trying to get food, have sex and avoid pain) and that different traits serve different functions and provide different benefits to the organism in striving after these goals.⁶

⁵Darwin is referring to Malthus his 1798 book *An Essay on the Principles of Population* in which Malthus wrote that “the power of population is indefinitely greater than the power in the earth to produce subsistence for man” [100, p. 7].

⁶Given this characterization and separation of Darwinism from evolutionary theory, one might wonder, for example, whether Fisher’s explanation for equal sex-ratios was not already a sign that Darwinism could not keep up with the theoretical development of evolutionary

3.3 Neo-Darwinism and the modern synthesis

Modern day evolutionary biologists accept both of Darwin’s core ideas, but they have significantly elucidated and elaborated the processes involved in and underlying evolution. One of the most important events in this context was the integration of Mendel’s theory of genetics and Darwin’s theory of descent with modification by natural selection into a single unified theory for describing biological evolution. This integration of Darwin and Mendel is referred to as the *modern synthesis*, a term coined by Julian Huxley in his 1942 *Evolution: The Modern Synthesis* [101, 102, 30].

The Modern Synthesis gave rise to population genetics [66], which was a mathematization of Darwinian evolutionary theory in which evolution was understood as “any change in the frequency of alleles within a population from one generation to the next” [65, p. 1], and which still provides the foundation of much of our contemporary understanding of biological evolution.

Another term often used in this context is *Neo-Darwinism*, even though this term, unlike the modern synthesis, is more nebulous in nature.⁷ The main difference between Darwin’s Darwinism and Neo-Darwinism, for the purposes of this thesis, is that Darwin’s Darwinism primarily concerned itself with making sense of biological evolution from the perspective of the organism while Neo-Darwinism primarily concerns itself with making sense of biological evolution from the perspective of the gene, also referred to as the ‘gene-centered view of evolution’ [103, 104].

3.3.1 Neo-Darwinism: Core ideas and concepts

The three main concepts used in Neo-Darwinism to make sense of biological evolution are *selection*, *fitness* and *adaptation* [94, 30]. Given that one cannot always distinguish between whether a trait increased because of ‘fate’ (i.e. because it increased fitness) or because of ‘luck’ (i.e. even though it did not increase fitness) an other important concept used to reconstruct the evolution of a given trait is that of *random (genetic) drift* or *drift* for short [105].⁸

Even though Neo-Darwinism’s focus is on genes, the organism still has an important role to play as the ‘survival machine’ that carries around these genes. It is for this reason that, within the Neo-Darwinian vocabulary, one still often talks

theory, because sex-ratios cannot be understood in terms of the ‘immediate benefits’ they provide to organisms without requiring natural selection to ‘look ahead’ in a Lagrangian manner.

⁷The terms modern synthesis and Neo-Darwinism are often used interchangeably. The way I have used these terms is as follows: The modern synthesis primarily refers to the *insight* that Darwin’s Darwinism could be combined with Mendel’s theory of genetics (which was initially understood as a theory about inheritance and not genetics). Neo-Darwinism primarily refers to Darwinism *after* the modern synthesis in which genes became seen as one of the central units of evolution.

⁸For a more technical treatment of the concept of ‘fate’ and ‘luck’ see section A.9. In short: If an outcome is overwhelmingly probable, one can say it is ‘fate’ when it occurs and ‘luck’ when it does not occur. It is for this reason that ‘fate’ is associated with the concept of *selection for* and ‘luck’ with the concept of *random drift*. The reason I introduce this vocabulary is because it is not always easy to determine whether a given outcome is ‘due to fate’ or ‘due to luck’, see section 3.5.1

about organisms, even though these organisms are understood as one-way extensions of the genome. In section 3.5.2 alternative perspectives are introduced that view the relation between organism and genome as a two-way interaction. In what follows I have chose to elaborate Neo-Darwinism in terms of *individuals* as such a treatment is general enough to allow for such differences in perspectives, as both gene and organism (and everything in between such as cells) can be treated as an individual in the Darwinian sense.

Fitness

Fitness is a measure of how well an individual ‘fits their environment’ or ‘how well adapted’ an individual is to the struggle for existence [96]. If individual A is more fit than individual B then individual A is more likely to survive and reproduce than individual B.

Selection

The process of natural selection requires two things: (1) Individuals must have different trait profiles and individuals with different trait profiles have different fitnesses while individuals with similar trait profiles have similar fitnesses (i.e. variation) and (2) the trait profile of offspring must strongly resembles the trait profile of the parent (i.e. heredity) [106]. If a trait systematically increases fitness, it is expected to increase in representation and it is said that there is selection *for* said trait [94]. If a trait does not increase fitness, but does increase in representation, then it is said that there is selection *of* said trait.⁹

Adaptation

If a trait systematically increases in representation over the course of many generations because it is selected for, such that, at some point, all individuals in a population (or even of a species) possess said trait (or variation), then said trait is said to be an *adaptation* [94, 107]. If an adaptation still increases fitness, then the adaptation is said to be *adaptive*.

If a trait is an adaptation, then the trait is an adaptation *to* some struggle the individuals of a population faced over multiple generations. A thick fur, for example, is an adaptation to the cold and hollow bones are an adaptation for flight [108]. Adaptations are often understood as ‘solving’ some ‘evolutionary problem’. Sober, for example, writes that “A is an adaptation for task T in population P if and only if A became prevalent in P because there was selection for A, where the selective advantage of A was due to the fact that A helped perform task T.” [94, p. 205].

Some adaptations used to be adaptive, but no longer are. These types of adaptations are called non-adaptive adaptations. Other adaptations are ‘layered’ in the sense that, initially they evolved as an adaptation to X (e.g. heat regulation), but then they continued to evolve and became an adaptation to Y (e.g. flight), something which is said to be the case for, for example, bird feathers. Such a ‘layered adaptation’ is referred to as an exaptation [109].

⁹This situation might happen when a fitness neutral trait is genetically linked to a fitness increasing trait.

Random genetic drift

Given that fitness increases the *chance* or *probability* an individual survives and reproduces, it is important to discuss the phenomenon known as *drift*, also referred to in the literature as *random drift*, *genetic drift* or *random genetic drift* [110, 111, 112, 113]. In populations in which fitness differences are very small or which consist of only a few individuals, fitness differences are not necessarily a reliable indicator of evolutionary outcomes. Given that most real life populations are neither infinitely large nor characterized by a massive spread in fitness, an important part of evolutionary research is devoted to figuring out whether a given evolutionary outcome was due to ‘luck’ or due to ‘fate’ [94, 105]. When presented with the fact that, for example, trait A is the dominant trait in a population, evolutionary researchers must figure whether the trait became dominant because it systematically increased fitness (i.e. due to fate) or whether the trait became dominant even though it provided no fitness benefit, nor was linked to any trait that increased fitness (i.e. due to luck).¹⁰

Darwinian evolutionary explanations

Neo-Darwinism’s central claim is that the process of natural selection and adaptation outlined above can, in principle, account for both the designed and purposive nature of organisms, as well as for the diversity of life from a single common ancestor (i.e. common ancestry). To this end, Darwinian evolutionary explanations are provided which show how, from beginning to end, a trait evolved in terms of a sequence of fitness increasing intermediate steps. This position is called gradualism in which organisms continuously and gradually develop and is at the foundation of Darwin’s Darwinism [69].¹¹

Evolution, beside requiring variation and heredity, also requires a mechanism which prevents the depletion of variation. Jenkins, for example, argued that if inheritance blended traits, eventually the variation in traits would ‘blend away’ [69, 118, 66]. Even though Darwin was not aware of any such mechanism, the modern synthesis solved this problem by incorporating Mendelian genetics and identifying processes such as recombination, cross-over, genetic mutations, etc. as constantly adding new variations to a populations gene pool [30, 64].

If a population exhibits differences in individual fitness, then said population will undergo a process of natural selection which, given enough time, will result in individuals whose morphology significantly differs from that of their distant past ancestors.¹² Furthermore, if the environment is sufficiently stable it is also true that *relative* fitness increases in the long run (i.e. over the timescale over which the environment is stable)[122, 49].¹³

¹⁰If an individual gets hit by a ‘random’ lightning strike, one would not, intuitively, consider this ‘selection event’ representative of the selection events the individual faces on a regular basis, like, for example, predation. One’s trait profile might significantly influence the outcome of a predation event, but not that of a lightning strike event.

¹¹Some authors have proposed non-gradualistic approaches to Darwinian evolution. Gould and Eldredge, for example, suggested the idea of *punctuated equilibria* to explain the large periods of ‘stasis’ in the fossil record [114, 115, 116, 117].

¹²Some authors contest this claim, claiming that beside differences in individual fitness, differences in trait fitness are also required [119, 112, 120, 121].

¹³Keep in mind that relative fitness can go up while absolute fitness goes down, if one expresses fitness in terms of reproductive success.

3.4 On Darwinism’s fragmented conceptual foundation

The reason I said Darwinism is not a single theory is because Darwinism suffers from a deep conceptual disunity and fragmentation. In this section I wish to show two examples of that disunity and the very real problems this disunity gives rise to at the level of actual evolutionary research. Population genetic type-recursion models, for example, conceive of natural selection as a discriminate sampling process and random drift as an indiscriminate sampling process with respect to fitness. In other words, natural selection and random drift are understood in terms of the *processes* that give rise to evolutionary outcomes. Using the Price Equation instead, however, results in one understanding natural selection in terms of the covariance between fitness and phenotype. In other words, natural selection (and by extension random drift) are understood in terms of the type of evolutionary *outcome* one obtains (i.e. how well the outcome conforms to expectation) [106] (c.f. [54, Ch. 6]).¹⁴ Consequently

The result is that a theorist deploying the Price Equation may treat as drift (that is, quantify as deviation from expectation) what a theorist deploying type recursion must treat as selection (quantified by fitness variables). [106, p. 10]

The Handicap principle is another a great example of the conceptually fragmented nature of Darwinism which, in turn, leads to confusion. About the “added burden and confusing logic of the Handicap Principle” [23, p. 267] Penn and Számadó write that

The semantic confusion began with Zahavi’s papers, which are like works of art: there are many interpretations about what he apparently meant to say, and different interpretations are treated as if they are equally valid. [23, p. 270]

This disunity does not, however, prevent the Handicap Principle from being “the most widely cited explanation for the evolution of reliable signals” [23, p. 267]. The core of the problem, I think, is that there is no canonical formulation and interpretation of Darwinism. As a consequence many authors have slightly different and often incompatible understandings of ‘the same concept’ which, in turn, leads to, for example, disagreements over the importance of kin selection and inclusive fitness in the evolution of eusociality [126, 98, 127, 128, 129, 130, 131].

One might consider such a plurality of formulations and interpretations a strength, but it also leads to unnecessary confusion and miss communication. Furthermore, it makes it unnecessarily difficult to effectively study and criticize Darwinian evolutionary theory from a philosophical perspective, because, as Sean Carroll would say:

One of the problems with God as a [scientific] theory, is that it is not a very precisely specified theory. [...] In fact, this is what I would argue: One of the check marks against God as a very good theory,

¹⁴Taking a physicist’s, as opposed to a biologist’s approach one might even come to the conclusion that there is no principle of natural selection to begin with [123, 124, 125].

is that if you try to say ‘Well here is why I do not believe in God,’ someone else will say, ‘Ah, you just do not understand what God is, God is completely different than that.’ [132]

This quote very much resonates with me in the sense that I feel that (potentially) valid criticism of this or that aspect of Darwinian evolutionary theory is often met with ‘but that is not *real* Darwinism’ or ‘author A claiming author B does not, in fact, understand how Darwinian evolutionary theory *actually* works’. Configurationalism is an attempt to show the conceptual unity of evolutionary phenomena. Providing a unified framework to make sense of all forms of biological evolution, as opposed to a fragment mosaic of incompatible ideas and understandings.

3.5 Neo-Darwinism: Philosophical problems

In the previous four sections I introduced some of the historic context and core concepts of Darwinism. In this section I will discuss three debates in the philosophy of evolutionary biology that are intimately tied to how one understands Darwinism: The nature of selection, the unit of selection and the nature of fitness debate. This section is not meant to settle these debates, but to provide an overview of the central problems these debates are about. In chapter 6 I will return to these topics and give a Configurationalistic take on these debates.

3.5.1 The nature of selection

Process vs outcome

One of the topics that philosophy of evolutionary biology concerns itself with is the nature of selection. One might ask, for example, whether natural selection should be understood as a *process* or an *outcome* [110, 133, 106]. Suppose for example that the fitness w_A of individuals with trait A is higher than the fitness w_B of individuals with trait B. Given that $w_A > w_B$ one would expect that, after some generations, the frequency ν_A of individuals with trait A is higher than the frequency ν_B of individuals with trait B.

But what if it turns out that $\nu_B > \nu_A$ as opposed to $\nu_A > \nu_B$? Does this mean that (1) there was selection for B because $\nu_B > \nu_A$ even though $w_A > w_B$ or (2) that there was no selection for B because $w_A > w_B$ even though $\nu_B > \nu_A$? If (1) one might argue that $w_A > w_B$ was incorrect based on the outcome and, therefore should, retroactively, be updated to $w_B > w_A$. If (2) one might argue that $w_A > w_B$ was correct and that $\nu_B > \nu_A$ is merely an unrepresentative outcome due to, for example, drift or other perturbing forces.

Proponents of natural selection as an outcome claim that for a process to be recognized as natural selection it must produce the *right outcome* while proponents of natural selection as a process claim that for an outcome to be recognized as natural selection, it has to be *for the right reasons*. An example might illustrate this distinction.

Suppose a population of prey is subjected to predation. Predation is modeled in two phases. In the first phase predators select a prey, in the second phase they hunt the prey. The selection phase is indiscriminate with respect to fitness while

the hunting phase is discriminate with respect to fitness. In other words fit prey are hunted as often as unfit prey, but fit prey are more likely to survive the hunt than unfit prey. If prey with A are fitter than prey with B then $w_A > w_B$ and one would expect $\nu_A > \nu_B$.

But what if, for some reason, it ‘just so happened’ that, over the time period the population was studied, lightning strike killed significantly more fit prey than unfit prey?¹⁵ Such a course of events would result in $\nu_B > \nu_A$ and one could reasonably doubt the appropriateness of classifying such an outcome as ‘due to natural selection’. It seems intuitively inappropriate to say that the lightning strikes collectively selected for ‘a lower running speed’.

Even though, in principle, the outcome is the product of a process of differential survival and reproduction, there is a ‘feeling of uneasiness’ in the sense that ‘the reasons seems to be wrong’. The outcome appears to be ‘due to luck’ as opposed to ‘due to fate’, since in general one expects predation and not lightning strikes to be the ‘main driver’ of an evolutionary outcome (again, see section A.9 for more on my use of the terms ‘fate’ and ‘luck’). Especially given that lightning strikes, unlike predation, do not seem to discriminate based on fitness: it seems intuitive to say that the prey that died due to lightning merely were ‘at the wrong place at the wrong time’.

Similarly, what if, for some reason, it ‘just so happened’ that, over the time period the population was studied, significantly more fit prey were hunted than unfit prey? Such a course of events would also result in $\nu_B > \nu_A$, but unlike the lightning strike examples, the reasons appear to be ‘better’ in the sense that the outcome is due to predation itself and not due to some unaccounted for outside interference. Would it still be reasonable to doubt the appropriateness of classifying such an outcome as ‘due to natural selection’?

And what if, for some reason, the lightning strikes ‘just so happened’ to kill significantly more B than A, resulting in $\nu_B > \nu_A$? Or what if, for some reason, the predators ‘just so happened’ to hunt more B than A, even though, it also ‘just so happened’ that during the hunting phase itself the proportion of A that died was equal to the proportion of B that died? In both scenario’s the outcome would be ‘right’ (i.e. as expected) but the reasons would be ‘wrong’ (i.e. not as expected).

Finally, suppose there is no lightning and no bias in prey selection, but one still obtains $\nu_B > \nu_A$, does that then mean $w_B > w_A$ and that the initial claim that $w_A > w_B$ was false? Perhaps, but one could still argue that, for what ever reason, fitness values only express a prey’s *ability* to survive a hunt in terms of a probability. The probabilities for A and B to survive a hunt might, for example, be $P_A = 0.7$ and $P_B = 0.65$. In principle, therefore, it could be that, even simply ‘due to luck’ more B survived the hunt than A.¹⁶

¹⁵Assuming both the targeting and outcome of a lightning strike event are indiscriminate with respect to the fitness differences within the population. The reason I say ‘just so happened’ is because such a categorization, in part, depends on our ignorance as evolutionary biologists about the exact micro-state of the universe. Would an observer knowing the exact micro-state of the universe be ‘surprised’ by any evolutionary outcome?

¹⁶This is, arguably, a sign that Darwinian evolutionary theory is unfalsifiable and it might be argued that, among other reasons, this was one of the reasons for Popper to claim that Darwinism was a metaphysical research program and not a testable scientific theory [134]. It

But how much luck is ‘too lucky’? A fair dice can, in principle, land on a six 10 or even 100 times in a row. But if one were to roll 10 or even 100 sixes in a row, one might reasonably suspect the dice had been tampered with. In other words, even though, in principle, the outcome of $\nu_B > \nu_A$ is compatible with $w_A > w_B$, it would raise suspicion about the factual correctness of $w_A > w_B$ since the result seems to be ‘too lucky’.

All of this is to say that the question of determining whether a given evolutionary outcome is due to natural selection or not, is complicated, especially since most evolutionary outcomes are unique and, therefore, hard to replicate. Furthermore, most of the time only a limited amount of information is available about the environmental factors involved, making it very difficult to determine whether a given trait evolved because ‘it was selected for’ (i.e. fate) or because ‘it just so happened to increase in frequency, even though we cannot find any reason in particular as to why said increase in frequency were to be expected’ (i.e. luck). Whether or not a given evolutionary outcome is attributed to natural selection or not therefore significantly depends on whether one conceives of natural selection as a process or an outcome.

Cause vs form

Another question one might ask is whether natural selection should be understood as a *cause* of evolution or a *form* of evolution. The underlying question is whether natural selection should be conceived of as the *process* of differential survival and reproduction itself or as the differential *ability* to survive and reproduce (i.e. fitness).¹⁷ In case of the former, natural selection is a form of evolution, since the process of differential survival and reproduction, that is, the differential increase and decrease of certain trait profiles, necessarily is a form of evolution using the definition in section 2.1. In case of the latter, natural selection might be construed as a cause of evolution, since without fitness differences, no change in the distribution of trait profiles occurs and, hence, no evolution occurs.¹⁸

Sober, for example, argues that Darwinian evolutionary theory should be understood as a dynamical theory about evolutionary forces, like natural selection, which *cause* a population’s trait distribution to change over time. In his view “natural selection—that is, selection for characteristics—is one of the causes of evolution” [94, p. 101]. More generally he writes that:

In evolutionary theory, the forces of mutation, migration, selection, and drift constitute causes that propel a population through a sequence of gene frequencies. To identify the causes of the current state [...] requires describing which evolutionary forces impinged. [94, p. 141]

This claim that natural selection is a cause of evolution, however, has not gone uncontested as some have argued that evolutionary theory is not a dynamical

should be noted, however, that Popper retract this claim later in life.

¹⁷In other words, the idea is that some individuals are better suited to a given environment, regardless of whether or not they actually increase in representation in said environment.

¹⁸See [135, 136, 137, 138, 139, 140, 141] for more on the concept of causation within evolutionary biology.

theory about evolutionary forces, but a statistical theory about the statistical properties of a population's fitness distribution [107, 112, 142, 120, 121]. About natural selection and drift they write that:

Selection and drift are not forces acting on populations; they are statistical properties of an assemblage of 'trial' events: births, deaths and reproduction. The only genuine forces going on in evolution are those taking place at the level of individuals (or lower) and none of these (and no aggregate of these) can be identified with either selection or drift. [112, p. 453]

Thus, from this 'statisticalist' perspective, natural selection is merely an emergent phenomenon coinciding with evolution, rather than causing evolution. The claims made by advocates of this 'statisticalist' perspective have, in turn, also been contested in the academic literature [143, 144, 145, 146, 147, 148].

3.5.2 The unit of selection

One of the problems already mentioned in the context of the struggle for existence was the question 'for whose benefit adaptations evolve'. The unit of selection debate arises when considering, for example, the evolution of altruism. In most evolutionary models, if one looks to the fitness differences *between* groups, then altruistic groups have a higher fitness than selfish groups, but if one looks to the fitness differences *within* groups, then selfish individuals have a higher fitness than altruistic individuals, regardless of which group they are in [97, 149, 150, 151, 152]. This raises the question, if altruism is an adaptation, then for whose benefit did it evolve? For the individual, or for the group? Another related question one might ask is 'which unit is the *ultimate* beneficiary of the evolutionary process?'. In other words, where and for whose benefit do adaptations accumulate? In *The Selfish Gene* Dawkins argues that

The fundamental unit of selection, and therefore of self-interest, is not the species, nor the group, nor even, strictly, the individual. It is the gene, the unit of heredity. [103, p. 32]

Such a 'gene-centered' view of evolution, however, has been called into question by proponents of *the third way* [153, 154, 155, 156, 104] and *the extended evolutionary synthesis* [157, 158, 159, 160, 161, 162]. On the website of the third way, for example, it is stated that "the DNA record does not support the assertion that small random mutations are the main source of new and useful variations" and that "Neo-Darwinism ignores important rapid evolutionary processes such as symbiogenesis, horizontal DNA transfer, action of mobile DNA and epigenetic modifications" [163]. Noble, one of the founders, goes as far as stating that

It doesn't make sense to retain a theory [i.e. Neo-Darwinism] that has been so fundamentally undermined on its central assumptions, i.e. the Weismann Barrier, the isolation of the genome from the organism and the environment, and the exclusion of Lamarckian forms of inheritance, since these were the central motivations of the Modern Synthesis. [164, p. 21]

Similarly, proponents of the extended evolutionary synthesis claim that "[The

extended evolutionary synthesis] maintains that important drivers of evolution, ones that cannot reduce to genes, must be woven into the very fabric of evolutionary theory” [165, p. 161]. They furthermore claim that Darwinian evolutionary theory needs to explicitly incorporate the various forms of non-genetic inheritance and their consequences for evolutionary outcomes [166, p. 710]:

In our view, this ‘gene-centric’ focus fails to capture the full gamut of processes that direct evolution. Missing pieces include how physical development influences the generation of variation (developmental bias); how the environment directly shapes organisms’ traits (plasticity); how organisms modify environments (niche construction); and how organisms transmit more than genes across generations (extragenetic inheritance). [165, p. 162]

It is important to note that proponents of the extended evolutionary synthesis do not consider their objections to the modern synthesis to be a mere “storm in an academic tearoom” but “a struggle for the very soul of the discipline” [165, p. 162].

3.5.3 The nature of fitness

Debates about the nature of fitness have multiple lines of inquiry. One line of inquiry, for example, is whether fitness is tautological, circular or otherwise trivial in nature [143]. If one defines the fittest as those that survive, it is trivially true that those that survive are also the fittest. Similarly, if one defines the fittest as those that produce the most offspring, it is trivially true that those that produce the most offspring are also the fittest. One might rightfully wonder whether differences in fitness, if so defined, explain evolutionary outcomes.¹⁹

Some evolutionary biologist have tried to sideline this problem of triviality by redefining the fittest such that ‘those that are fit are *more likely* to survive’ thereby not making it trivially true that those that survive are, by virtue of surviving, fitter.²⁰ Unless, however, one can measure fitness independently of actual survivorship, this redefinition still reduces to triviality: If those that are fitter are more likely to survive, then it is also trivially true that those that survive are more likely to be fit.²¹

Another line of inquiry might be whether fitness should be understood as the rate at which a trait is expected to increase in representation within a given population (i.e. a growth rate) or as an individual’s ability to survive and reproduce (i.e. a disposition) [112]. Given the example provided in section 1.1.4 in which organism A lived 60 days and produced 70 offspring and organism B lived 80 days and produced 80 offspring, it seems that, from the perspective of

¹⁹The suspicion is that one explains the outcome in terms of the outcome. Explaining that someone won a race because they were faster, for example, though not wrong in and of itself, is rather uninformative. One would much rather have an explanation in terms of how, for example, the winner used a special engine with more torque and special wheels with more grip.

²⁰The same line of reasoning can be applied to fitness if defined in terms of reproductive success.

²¹This logic only works for binary decision. If there was a third alternative to survive or not survive then it might be, for example, that even though most that survive are fit, that most that are fit do the alternative as opposed to surviving.

evolution itself, only trait (profile) fitness matters in terms of the rate at which a trait increases in representation. A further problem is that if fitness is not just the (expected) growth rate of a given trait profile, but a true reflection of an individual's ability to survive and reproduce, that it is unclear how to measure (or estimate) this ability in a generally applicable manner [119, 143, 167, 96].

3.6 Chapter summary

Darwinism is predicated on two core ideas: The idea of biological design and the idea that there is a struggle for existence. The goal of Darwinism is to explain the existence of biological design by showing how the designed and purposive nature of organisms (i.e. its physical traits and behaviors) are the product of the process of natural selection operating on incremental fitness differences. The modern-synthesis combined Darwin's Darwinism with Mendelian genetics and, in doing so, solved the problem of blending inheritance. Contemporary Neo-Darwinism builds forth on this modern-synthesis and makes sense of biological evolution from the perspective of the gene.

The nature of selection debate concerns whether natural selection should be understood as a process or as an outcome and whether or not natural selection is a form or a cause of evolution. The unit of selection debate concerns for whose (ultimate) benefit adaptations evolve and accumulate and what the unit(s) are on which natural selection, if it is an evolutionary force, acts. The nature of fitness debate concerns whether fitness should be understood as the growth rate of a trait profile expressing its increase in representation or a disposition of an individual expressing its ability to survive and reproduce.

These observations raise the following question: is evolution truly about individuals, and in particular organisms, and their struggle for existence? Or, as the unit of selection debate might have already suggested, is there more to evolution, and in particular to fitness, than 'does this trait benefit me?'.

Chapter 4

Configuralism

“Outside my mind, nothing is real.”

– Carl, *The Invoker*

In this chapter the conceptual ontology of Configuralism is introduced and its implications for questions about the representation of patterns are analyzed using weighted configuration spaces. The primary purpose of this chapter is to develop a framework which is applicable to the full domain of empirical inquiry, not just the biological domain. The reason for this is two fold.

First, by building Configuralism from the ground up it firmly establishes that the trait spaces in chapter 5 are ‘nothing but’ coarse grained version of the configuration spaces developed in this chapter. This is important, as it justifies the claim that the Configuralistic interpretation and formulation of evolutionary theory developed in chapter 5 is, unlike Darwinism, fully reducible to and compatible with (both empirically and conceptually) a classical Newtonian description of physical reality, as discussed in section 1.4.2 (but see appendix A for a more general reductive basis).

Second, by showing that traits and trait-carriers are ‘nothing but’ the arbitrary product of how one individuates patterns in perception, independent of the actual configurations from which they derive, the artificial and arbitrary distinctions discussed in section 1.4.3 are relegated to being nothing more than artifacts of the manner in which human perception individuates patterns in perception, as opposed to some reflecting some deep or ontic distinction between different configurations of matter within the physical realm.

4.1 From Darwinism to Configuralism

As explained in section 1.2 Configuralism (1) rejects the idea that biological design is real and in need of a scientific explanation and (2) generalizes the struggle for existence from being about individuals competing for survival and reproduction to being about patterns and their competition for volumetric occupation.

Darwinism’s central goal was, and still is, to explain the existence of biological design. Given that Configurationalism rejects the notion of biological design, it is necessary to specify in which manner Configurationalism is a continuation of Darwinism. The important thing to observe, is that even though Darwinism’s goal is to explain biological design, the questions it answers are often of the form ‘why is trait A more abundant in population P than trait B?’. It then answers this question in terms of how individuals with trait A were better adapted at the struggle for existence than individuals with trait B.

In other words, it answers a question of the type ‘why does one see more A than B’, and, since this question does not make explicit references to biological design, it can be answered from a Configurationalist perspective in terms of the differential spatial expansion and temporal propagation of patterns. Configurationalism might not be able to ‘explain’ why individuals ‘look designed’ or ‘how a trait benefited an individual’, but it can show the circumstances and critical conditions under which a given trait increases in representation within a population.

4.2 Configurationalism’s conceptual ontology

4.2.1 The atomic-grid

Configurationalism has a very minimalist conceptual ontology, for it mainly concerns itself with the patterns that feed into our perception and not with the specific way through which they are realized. Whether or not the world truly consists of particles, for example, is only of minor consequence. Even though I will present Configurationalism using an atomic-grid ontology, there is nothing inherently special about this atomic-grid ontology other than that it provides a conceptually clean way to introduce the core concepts and ideas of Configurationalism (again, see appendix A for a more general treatment).

The atomic-grid ontology conceives of physical reality as a large three dimensional grid. At the center of each cube in the grid an atom can be placed and atoms come in different types. Time ticks in discrete steps and patterns are realized by configurations of atoms in the atomic grid.

Most patterns in human perception, however, are macroscopic in nature. A macroscopic pattern like the species ‘dog’ has many different atomic configurations which all realize the pattern ‘dog’ in physical reality. Furthermore, even for a single realization of the pattern ‘dog’ many different atomic configurations realize this single ‘dog’ over the course of its lifetime. It is for this reason that patterns are associated with (large) sets of (slightly different) atomic configurations which all realize the same pattern in perception.

Furthermore, patterns can have subpatterns. Figure 4.1 for example, shows a selection of hypothetical subpatterns for the pattern dog based on the color of the dog. The core idea is that the atomic configurations which realize the pattern ‘green dog’ in perception are a subset of the atomic configurations which realize the pattern ‘dog’ in perception. In principle, every variation in the configuration of atoms that realize the pattern ‘dog’ in perception constitutes a subpattern of that pattern.

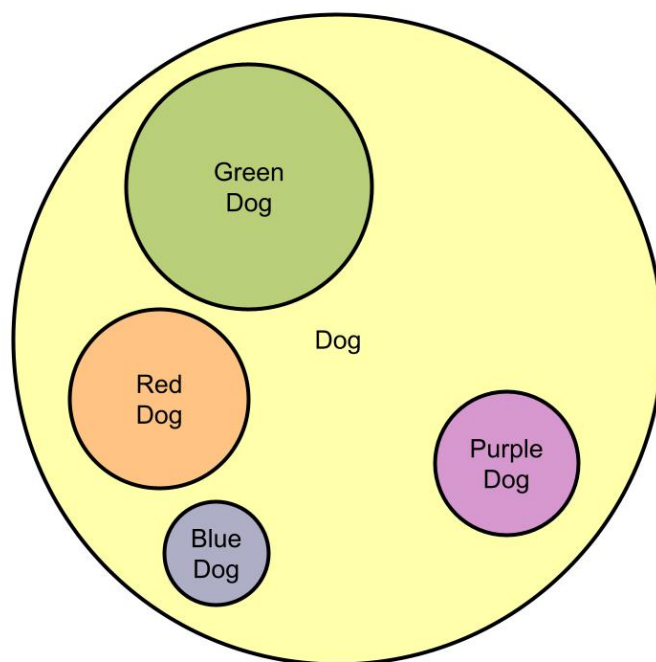


Figure 4.1: Visualization of pattern and subpattern relationship. The atomic configurations which realize ‘green dog’ in perception are a subset of the atomic configurations which realize ‘dog’ in perception.

4.2.2 Patterns and configurations

Patterns, however, are not static. It is not just about identifying a specific configuration of atoms as realizing a given pattern, it is also about identifying a specific sequence of configurations of atoms as realizing a given pattern. Recognizing a dog is one thing, recognizing that the dog is running is another. The ‘running’ pattern does not merely refer to a large set of atomic configurations, it refers to a large set of sequentially bound subsets of atomic configurations.

The fact that the atomic configuration associated with ‘eating dog’ and the atomic configuration associated with ‘running dog’ are identified as dog mainly has to do with the specific arrangement of atoms in the atomic configuration. The fact that the ‘eating dog’ is identified as ‘eating’ is not only because of some specific atomic configuration, but because of a well defined sequence of atomic configurations. Similarly, a dog must ‘grow up in the right order of phases’ for it to be a dog. The changes an organism undergoes during its lifetime are as much part of what makes it belong to a certain species as its physical constitution in adulthood [168]. Most patterns are an intersection of more general patterns, eating dog, for example, is a pattern which lies on the intersection between the pattern ‘eating’ and ‘dog’ (see figure 4.2).

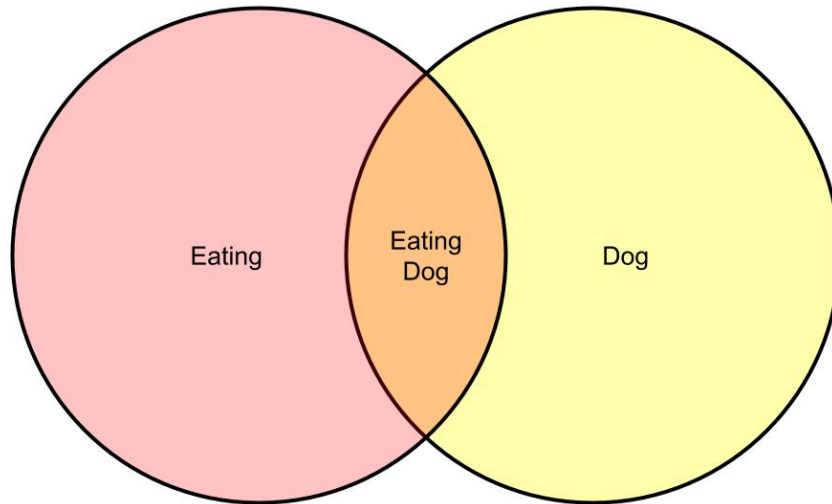


Figure 4.2: Visualization of pattern ‘eating dog’ as the set of configurations defined by the intersection of the patterns ‘eating’ and ‘dog’.

4.2.3 Patterns in perception: The eyes as spatio-temporal integrators

The human eye is like a film camera. Each pixel on each frame in a film integrates all the photons coming from a given spatial region over a given time period into a single pixel consisting of a color and a luminosity. The color is determined by the average wavelength of all the photons hitting the pixel over a given time interval and the luminosity is the sum of all the photons hitting the pixel over that same time interval. In short, eyes are like spatio-temporal integrators. They do not reflect reality as it truly is, they reflect reality in terms of spatio-temporally integrated units which, together, produce ‘vision’.¹ It is for this reason that your vision has a ‘certain refresh rate’ and a certain ‘optical resolution’. One cannot, due to this spatio-temporal integration process, observe change that is ‘too fast to register’ or ‘too small to resolve’.

This is an important observation when asking the question ‘why do we see more A than B?’. What we ‘see’ or ‘perceive’ is not necessarily reality itself and when we ask why a certain pattern in our perception is more abundant than another pattern, we must first verify whether or not this is due to *physical biases* or due to *perceptual biases*.

In a room in which there are an equal number of $\lambda = 550$ nm sources (i.e. visible light) and $\lambda = 900$ nm sources (i.e. infrared), for example, it would be

¹This is where section 2.4’s more general *properties when probed* come from. Even atoms are, at the most fundamental level, nothing but invariant properties when probed.

incorrect to conclude from the fact that one observes more $\lambda = 550$ nm than $\lambda = 900$ nm photons, that nature has a bias for $\lambda = 550$ nm photons. The bias, in this scenario, is completely perceptual. Nature does not ‘select’ for $\lambda = 550$ nm photons, your eyes ‘select’ for $\lambda = 550$ nm photons.

More generally, when asking why pattern A is more abundant than pattern B, one must first establish to which extend the discrepancy in representation is due to perceptual biases as opposed to dynamical biases, before one can conclude that ‘nature selects or prefers A over B’. Suppose, for example, that objective reality is as show in figure 4.3. Suppose further that perception transforms the objective reality shown in figure 4.3 using the following rules: for each four by four grid unit if (1) there are less than 5 red squares the grid unit is perceived as yellow; if (2) there are less than 5 yellow squares the grid unit is perceived as red; if (3) there are more than 4 but less than 12 red (or yellow) squares the grid unit is perceived as orange. Application of these transformation rules results in the perception shown in figure 4.4.²

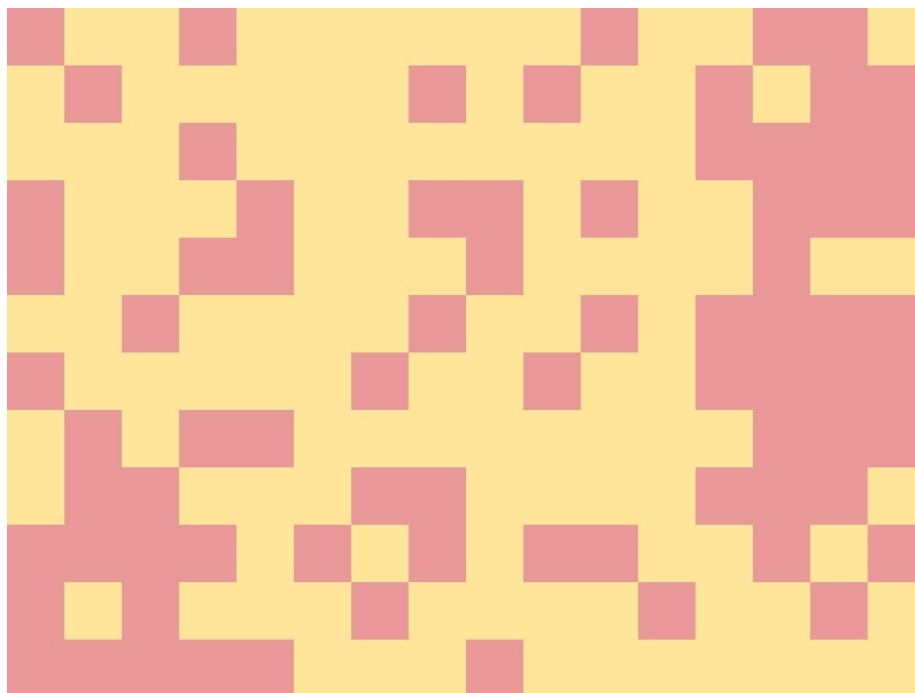


Figure 4.3: A two dimensional reality consisting of yellow and red squares tilling a spatial grid.

The first thing to note, is that in perception one can perceive things that are not objectively out there: In the example the color orange does not exist at the

²The transformation shown in figure 4.4 is not unique, as it significantly depends on which square in the grid one begins the transformation. For sufficiently large grids with sufficiently small grid units of integration in which the patterns are many times larger than the grid unit and change in a smooth and continuous enough fashion, however, deviations in the final outcome of the transformation process due to where one starts the transformation are negligible.



Figure 4.4: The perception obtained after transforming the two dimensional spatial grid of figure 4.3.

most fundamental level.³ The second thing to note, is that the perception of, for example, the color orange is not uniquely associated with a single configuration of red and yellow squares in a four by four grid. In other words, the perception of orange is associated with the set of micro-configurations which meet the criteria specified in rule (3). Taken together these micro-configurations can be referred to as a macro-configuration, similar to how in statistical physics one can have a set of micro-states realize a macro-state.⁴

Given that, in principle, every micro-configuration of the universe is unique, does it even make sense to ask if there is a dynamical bias for why one sees one pattern more often in perception than another? The grouping of micro-configurations into macro-configurations is not nature's doing, but our own.

³This does not mean that the sensory experience of the color orange is not an objective fact, nor that the configurations which give rise to this sensory experience are not objectively out there. It also does not mean that, because a description of physical reality is not fundamental, that therefore it is not objective: A description of reality can be objective, even if the entities used in the description are not *objectively out there* in the sense of being *ontically individuated entities* at the fundamental level.

⁴The difference between a configuration and a state is, that a configuration only contains information about the arrangement of matter at a certain point in time while a state also includes dynamical information about, for example, the velocity and mass of particles, allowing one to make accurate predictions about the future configurations a system will be in. Given that one does not perceive the velocity or mass of a particle, but only its location, configurations are at the foundation of visual perception. Velocity and mass are values inferred from a sequence of configurations, in which a pattern realized at $t = t_1$ is *re-identified* as the same pattern at $t = t_2$.

An alien unable to ‘see’ patterns other than two micro-configurations being exactly alike would have a hard time understanding the macroscopic concept of a species. What looks like two instantiations of the *same* species to us would look like two unrelated configurations to the alien. Till what extent, therefore, is the fact that some trait A is more abundant than some trait B more than just an artifact of our perceptual biases?

But all is not lost. If, for example, nature has a dynamical bias in which micro-configurations of type A tend to decay to micro-configurations of type B, one can still explain why one observes more macro-configurations realized by micro-configurations of type B than of type A by means of dynamical bias, even though the fact that one associates micro-configurations of type A and B with certain macro-configurations is, in and of itself, a purely perceptual bias.

4.2.4 On the metaphysical status of patterns: What are they and do they exist outside of the mind?

It should be noted that patterns, as discussed in the context of Configurationalism, are purely perceptual in nature. The configurations that realize a pattern in perception are ‘out there’, but the pattern itself is not. The pattern only ‘exists’ in relation to a perceiver, just as code only exists in relation to an interpreter. Whereas Dennett, for example, would argue that a configuration *displays* a pattern [169, p. 31] and that this pattern would exist even if invisible to us [169, p. 34], Configurationalism would argue that one can only *recognize* a pattern in a configuration and that the pattern is only ‘real’ in so far as it is being recognized.

To illustrate this last point. Even if it is an objective fact that *if* a human observer were present at some location that said human observer would experience some pattern P in perception, it does not follow that, therefore, pattern P exists *independently* of the human observer. There is no reason to suppose that a different type of observer would, at the same location, experience the same pattern P as opposed to some other pattern P’. Just because it is an empirical maxim of the natural sciences to assume that the configuration of matter which gives rise to P is invariant under a change of observer, does not mean that the pattern P itself is invariant under a change of observer. A Configurationalist would argue that Dennett’s mistake is to assume that because a configuration *displays* a pattern *in relation to a human observer*, that therefore the configuration *displays* said pattern *to all observers* and, hence, might be considered an inherent or objective property of the configuration in question, independently of the observer observing said configuration.

4.3 The ease of realization

4.3.1 Essence of the idea

The idea behind the ease of realization is best illustrated using an example. Suppose one is provided a two by two grid in which each square can be colored either yellow or red. The sixteen possible ways to color the two by two grid are

shown in 4.5.⁵

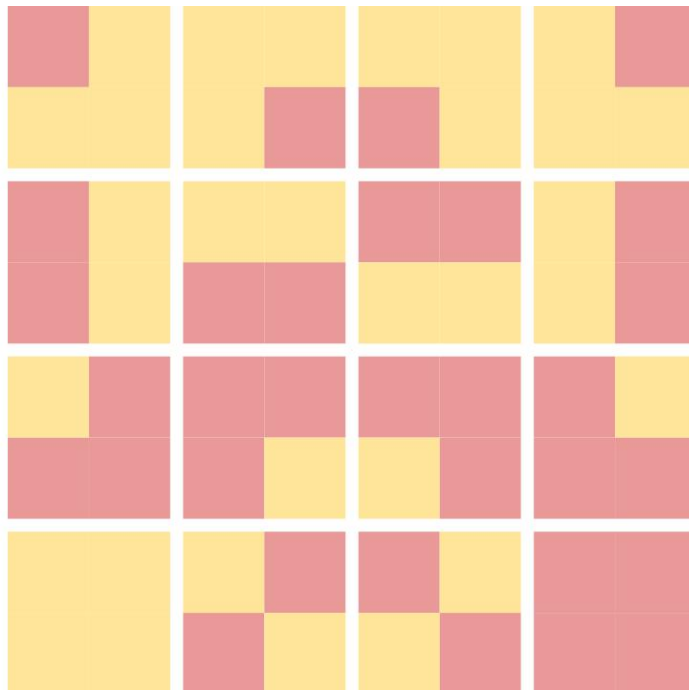


Figure 4.5: There are sixteen possible ways to color a two by two grid with two colors.

Suppose one used the following transformation rules: (1) if there are no red squares then the grid is perceived as yellow; (2) if there are less than three red squares the grid is perceived as orange; (3) if there are three or more red squares the grid is perceived as red. Using these rules would result in the transformation shown in figure 4.6.

A large collection of random grids would show no bias at the level of micro-configurations, because the representation of each micro-configuration would be 1/16-th. At the level of macro-configurations, however, there would be a bias, because the representation of orange would be 10/16-th, red 5/16-th and yellow 1/16-th. In other words, given that there are more micro-configurations which realize orange, it is easier to realize orange than it is to realize yellow in the absence of dynamical bias.

If one were to include a dynamical bias, however, the representation of orange, red and yellow in perception would evolve over time. If, for example, every unit time a red square decays in a yellow square, the ‘weights’ of each macro-configuration would change as depicted in figure 4.7. Even though it is not easy to realize a yellow macro-configuration by randomly placing red and yellow squares in a grid, it would be very easy to realize a yellow macro-configuration by waiting four or more units of time after realizing a random micro-configuration. In other words, if you were to look at a large collection of random grids you

⁵If one is bothered by the fact I am not using arguments from symmetry to reduce the possibility space, then assume each square in the grid has a unique identifier.

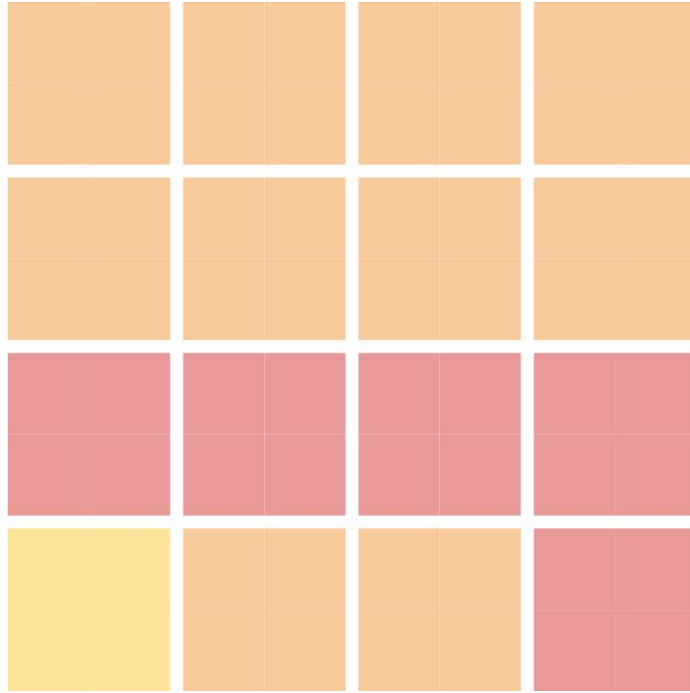


Figure 4.6: Using the transformation rules described in this section, the grid is transformed to one yellow, ten orange and five red grids.

would initially see more orange than yellow, but after a sufficiently long time you would see more yellow than orange.

4.3.2 Formal elaboration

Without dynamical bias

For the example presented above, one can easily deduce that the configuration space associated with the grid transformation consists of 16 distinct micro-configurations that realize 3 distinct macro-configurations. In the absence of dynamical bias the macro-configuration ‘yellow’ has weight $\frac{1}{16}$, the macro-configuration ‘orange’ has weight $\frac{10}{16}$ and the macro-configuration ‘red’ has weight $\frac{5}{16}$.

Conceiving of the universe as grid of atoms with n distinct atom types and N available grid locations the ease of realization E is calculated as

$$E = \frac{m}{n^N}, \quad (4.1)$$

where m is the total number of configurations of atoms that realize a given pattern P in perception within the volume V specified by N .

It is important to note that, generally speaking, $mi \propto N$, where i is the number of times a pattern P is identified in V. Effectively this means that the ease of realization is size normalized. Larger patterns have more configurations of atoms that realize the pattern, but also require more grid locations. It is the ratio of

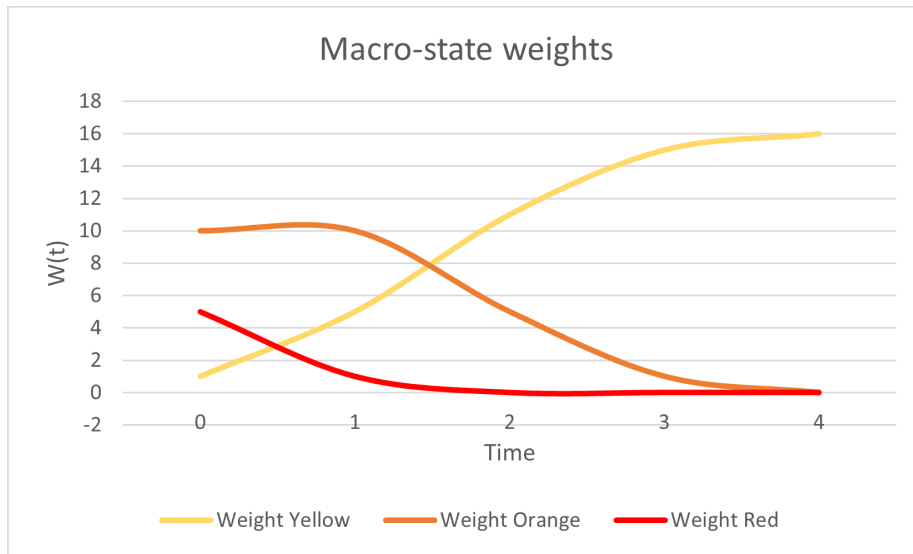


Figure 4.7: The distribution of the orange, red and yellow macro-states at $t = 0$ is 10:5:1 respectively and purely the result of perceptual bias. The distribution at $t = 4$ is 0:0:16 and purely the result of dynamical bias.

configurations that realize a pattern and the total number of configurations possible within a specified number of grid locations that matters. A pattern P_a which requires $N_a = 8$ grid units and is realized by $m_a = 4$ configurations is, for example, easier to realize than a pattern P_b which requires $N_b = 16$ grid units and is realized by $m_b = 5$ configurations, even though, at face value $m_b > m_a$.

With dynamical bias

In the presence of dynamical bias the ease of realization purely defined in terms of the ratio of configurations that realize a pattern P in a given volume V divided by all possible configurations in V will not suffice. Instead one must tend to the weighted configuration space of the atomic configurations of a system in which each configuration is weighted in order to account for the presence of dynamical biases. These weights $w(t)$ are a function of time, as the configurational evolution due to the dynamical biases is a temporally extended *process*.⁶

To compute the weights $w(t)$ requires one to, in general, analyze both the configuration-space as well as its underlying state-space. To draw the analogy with Newtonian physics, only knowing the position of particles might allow one to analyze the distribution of patterns realized in perception, but it will not allow one to make predictions about the future distribution of patterns realized in perception. This is because besides requiring the location of a particle, one

⁶In principle there is another set of weights which corrects for the number of times a pattern is realized within a given configuration of a given system in terms of the total ‘volume’ said pattern occupies. Even though the introductory discussion in this section does not explicitly incorporate the weights associated with a pattern’s multiplicity of realization *within* a single configuration, one can simply view the weights I introduce in this section as already corrected for said bias as such a correction is more of a technical afterthought than a deep conceptual insight.

also requires to know, for example, its velocity, acceleration, mass, etc. in order to make predictions about the future configurations of a system.⁷ In other words, a single configuration in configuration-space can be realized by a multitude of states in state-space. The complexities of this state-degeneracy depend on the types of dynamical bias present, but, as will be argued in section 4.4.1, the exact details of this relation can largely be ignored using top-down analysis as opposed to bottom-up analysis.⁸

Dynamical bias, in its most general form, merely entails there is a sequence of micro-configurations, and that the micro-configurations in this sequence are ordered in such a way that, from the perspective of macro-configurations, certain macro-configurations consistently ‘evolve into’ other macro-configurations. In other words, the sequence of micro-configurations is not random from the perspective of the macro-configurations they realize. This means there are recurring sub-sequences of macro-configurations, even though, from the perspective of the micro-configurations that realize these recurring sub-sequences of macro-configurations there might be no recurring sub-sequences of micro-configurations (see appendix A for a more technical treatment).

The ease of realization of a pattern P realized by the set of configurations $C = \{c_1, \dots, c_m\}$ in the presence of some dynamical bias in a given volume V after a time interval t is given by

$$E(t) = \frac{\sum_{i=1}^m w_i(t)}{\sum_{j=1}^N w_j(t)}, \quad (4.2)$$

where j sums the weights $w_j(t)$ over all N possible configurations c_j in V at time t . The values of each $w_i(t)$ and $w_j(t)$ at the initial time $t = 0$ are all equal to 1 unless further information is provided to narrow down the set of all *in principle* possible micro-configurations in V to a smaller subset of all *in actuality* possible micro-configurations.⁹

This last point is important, because one usually has knowledge of a system’s macro-configuration, but not the specific micro-configuration which realizes that macro-configuration. In practice, therefore, one does not assign equal probabilities to each and every micro-configuration possible in V , but to each and every micro-configuration possible in V which also realizes the observed macro-configuration.

⁷This statement, though correct from a physicist’s perspective, is problematic from an epistemic perspective, for it is analysis of configuration-spaces from which state-space descriptions are derived. Velocity, for example, even if an ontic-property, is epistemically speaking, derived from the difference in location between ‘the same’ macro-configurations at different times.

⁸Keep in mind that the true evolution of any system is, in principle, a single state with normalized weight 1 moving from one point in configuration space to another. Furthermore, in the absence of dynamical bias the probability that a macro-configuration is going to be realized at some time t is, at all times t , exactly equal to the number of micro-configurations which realize said macro-configuration (i.e. $w(t) = w(0)$ for all t) Moreover, these weights are used to express epistemic ignorance and not ontological underdetermination.

⁹One could have normalized the weights $w(t)$ so that at $t = 0$ they would all be $1/N$, but such a procedure is of no conceptual importance and unnecessarily clutters the math. See [170] for potential problems with the principle of indifference used to justify the principle of equiprobability. Given that the ease of realization is an epistemic approach, however, a lack of objective probabilities poses no deep metaphysical problem.

Coarse graining configuration space

Most patterns are associated with a large number of micro-configurations c whose collection as a whole can be described as a macro-configuration C which realizes a given pattern in perception.¹⁰ Using this approach any sequence of configurations in a finite volume over a finite time period can be described in a tractable manner using the weights $w(t)$. Dynamical bias involving a non-finite number of micro-states that realize a given micro-configuration might not be tractable however using a bottom-up approach (see also appendix A.10).

In most scenarios, however, one only cares about whether a given system evolves from one macro-configuration to another macro-configuration. The exact micro-configurations involved in such an evolution are deemed irrelevant. A macro-configuration's weight $W(t)$ is the sum of the weights $w_i(t)$ of its associated micro-configurations, given by:

$$W(t) = \sum_{i=1}^m w_i(t). \quad (4.3)$$

If one 'coarse grains enough' one can create a configuration space in which the macro-configurations correspond to distinct trait variations of organisms (see also appendix A.2). This property shall be used in chapter 5 to analyze biological evolution in terms of a sequence of states in *trait spaces*, in which each state represents the distribution of traits within a population P of individuals I in some environment E . The total volume in this scenario is defined by the environment as a whole, and, in principle, each state of the population in trait space is realized by set of micro-configurations in the target volume specified by the environment

4.3.3 Evolutionary implications

One of the insights that follows from the ease of realization is that if the configurations which realize pattern A are a sub-set of the configurations which realize pattern B, then it logically follows that pattern A is equal to or more abundant in perception than pattern B, regardless of dynamical bias. Why does one observe more mammals than dogs? Because dogs are a sub-pattern of the pattern called 'mammal' (see figure 4.8).

Another insight is that the ease of realization can be used to make sense of evolutionary constraints that bias the outcome of natural selection. In principle, there is only one true evolution of an evolutionary system, but given we only know the system's macro-state there are many different evolutions possible depending on the exact micro-state that realizes the system's macro-state.¹¹ If there are significant biases in the evolutionary trajectories through configuration-space based on the micro-state distribution, this can explain why some 'evolutionary

¹⁰Just to clarify using the example of the outcome distribution of an ordered collection of coin flips, a macro-configuration might be 3 heads and 2 tails while a micro-configuration realizing this macro-configuration might be HTHHT.

¹¹An evolutionary system also includes the dynamics with the environment, hence the state-space. A population's trait distribution or trait space representation would, however, be a configuration space

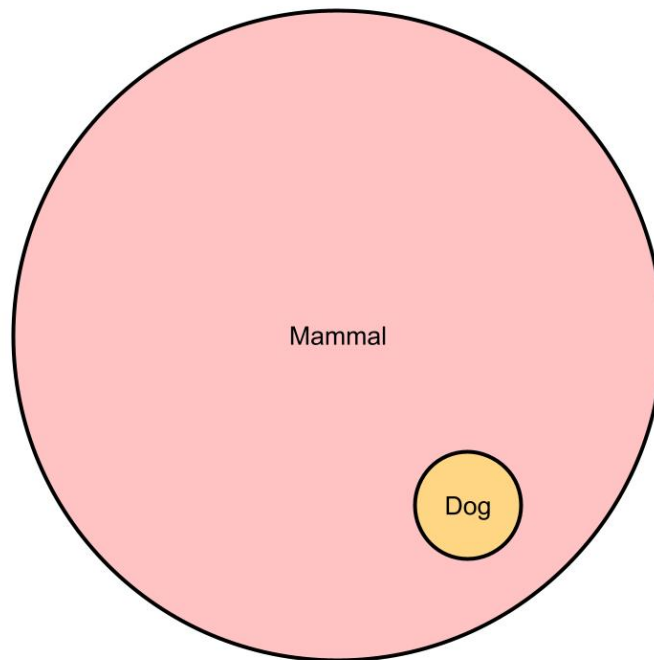


Figure 4.8: One will always see more mammals than dogs, since dog is a fully contained subpattern of mammal. The atomic configurations which realize the pattern ‘dog’ in perception will, at all times, also realize the pattern ‘mammal’ in perception.

paths’ are more likely than others in terms of how, over time, some regions in configuration space become more weighted while other become less weighted.

Suppose, for example, that one wants to explain the fact that most flying species have an even distribution of wings along their front-to-back line, one can use the ease of realization perspective to understand that, if there only is selection for flight, an even distribution of flight organs around this line is the easiest to realize. This follows from the fact that flight requires a symmetric distribution of lift generating organs around an organism’s center of mass and that organisms already are, by en large, line-symmetric along their front-to-back line. Hence, the configurations with an even number of lift generating organs along an organism’s front-to-back line are more heavily weighted than other lift generating configurations. One might thus conclude that there was selection *for* flight, but not necessarily *for* symmetric or even numbered wings, rather, those were the *easiest to realize* evolutionary paths given past evolutionary constraints.

4.4 Practical application

Studying a macroscopic phenomenon like biological evolution using weighted configuration spaces is not particularly practical. Even if one coarse grains their weighted configuration space to obtain a trait space describing the relevant macroscopic configurations necessary to describe biological evolution in an intuitive vocabulary, one is still faced with the fact that one needs to know the

$w_i^j(t)$ for each configuration c_i^j within one's target volume V in order to calculate the weights $W_j(t)$ to make predictions about the distribution of macro-configurations C_j .

Even though, in principle, such a calculation can be done, the sheer size of the configuration space necessary to describe biological evolution, not to mention the even larger size of the underlying state space, makes such a bottom-up approach undesirable. There is, however, a way to approximate these weights using a top-down approach. The idea is introduced in the next section using the example of coin flips.

4.4.1 Top down probabilities

Suppose one is given a coin and asked to determine whether or not the coin is fair? One way to determine that the coin is fair, is to take a bottom up approach and analyze the coin's mass distribution. This approach, however, is very time consuming and measuring the mass distribution of a coin requires specialized equipment not available to everyone. Thus, unless absolute certainty is of the essence, one might consider approximating the fairness of the coin using a top down approach: simply flip the coin a few times and note down the outcome distribution.¹²

If, after a considerable amount of flips the coin's outcome distribution shows a roughly 50:50 distribution of outcomes, one might infer that the coin is 'fair enough' that one is willing to make predictions about future outcome distributions under the assumption that the trend observed in the coin's past outcome distribution will hold for future outcome distributions.

Obviously there is a certain degree of error involved in this process. Nothing prevents an unfair coin from, in principle, yielding a 'fair' outcome distribution. Just as nothing prevents a fair coin from, in principle, yielding an 'unfair' outcome distribution. The probability that an unfair coin yields a fair outcome distribution and a fair coin yields an unfair outcome distribution might be very low, but very low does not by default equate to negligible. Furthermore, even if one is able to discriminate between 'grossly unfair' coins and fair coins using outcome distributions, this still leaves room for 'slightly unfair' coins to be confused for fair coins: It might be easy to tell a 70:30 from a 50:50 using a hundred coin flips, but the same cannot be said for telling a 49.99:50.01 from a 50:50.

Furthermore, suppose that one is given a collection of ten million coins and one is asked to determine whether the coins in this collection are, on average, fair. In other words, one is not just asked to determine whether individual coins in the collection are fair, but also whether the collection as a whole is fair. A collection of fair coins is, obviously, fair, but in principle, if the collection has a 'fair' distribution of unfair coins, the net probability of picking a random coin from the collection and flipping it heads might still be 50:50. If the collection, for example, contains 5 million coins with a 70:30 and 5 million coins with a 30:70 probability, then the net probability of picking a coin and flipping heads is equal to the net probability of picking a coin and flipping tails.

¹²See [171, 172] for more on coin flip probabilities and physics.

Suppose, however, that we do not really care about whether the individual coins in a collection are fair, but only if the collection as a whole is fair. In this case, instead of flipping individual coins, we might simply pick a few hundred coins from a collection, flip them once, and note down the distribution of outcomes and infer the fairness of the collection as a whole from that.

This last approach can also be used to approximate the distribution of weights $W(t)$. Instead of computing the distribution of macro-weights $W(t)$ based on the micro-weights $w(t)$, one approximates the distribution of macro-weights $W(t)$ by sampling individual $w(t)$ over a given region of space and time. One then infers the distribution of $W(t)$ from the distribution of $w(t)$ in order to make predictions about the future distribution of macro-configuration within said region of space and time.¹³

4.4.2 On the importance of timescales

Even though one might not have absolute certainty, one can make reasonable inferences about $W(t)$ based on observing the distribution of patterns in a given volume over a given period of time. If, for example, pattern A occupies more volume than pattern B at time $t = 0$ but, between $t = 0$ and $t = t_1$ one observes that pattern B increases more rapidly in volume than pattern A, one might infer that at some future time t_2 pattern B will occupy more volume than pattern A. Furthermore, if one takes a sub-sample of both pattern A and pattern B and brings them together in a smaller target volume, one can make reasonable inferences about what happens when pattern A and pattern B get into direct competition for volume.¹⁴

Using such methods one can still make accurate enough predictions about the future distribution of macro-configurations, even though one does not determine the likelihood (i.e. the ease of realization) that a given pattern will occupy a given amount of volume based on the analysis of weighted configuration spaces. One can, for example, explain why one sees more A than B in terms of the differential rates at which A and B's volumetric occupation changes. One might even analyze how these rates of expansion vary over time and with the environment to determine the distribution of A and B in both the short term and the long term.

It might be, for example, that B increases more rapidly in volumetric occupation than A early, but has a rate of expansion that goes down over time due to, for example, an increase in the number of B already realized such that, after some critical time t_c , A increases in volumetric occupation more rapidly than B. The important question in such a scenario is whether or not A can 'survive long enough' to make it to t_c . In other words, if A and B are struggling against

¹³The underlying idea is to use sub-sample analysis to find trends which can be extrapolated for predictive purposes. If one flips 100 coins and obtains a 50:50 outcome at $t = t_1$, a 55:45 outcome at $t = t_2$ and a 60:40 outcome at $t = t_4$ one can infer that, at $t = t_5$ the outcome will be 65:35. The initial distribution might be due to perceptual bias, but assuming perceptual bias is time-independent, the subsequent change in outcome distribution is due to dynamical biases (i.e. the change in the mass distribution of the coins).

¹⁴This last step is important, because if A is a more established pattern and B is a newer pattern, then B might increase rapidly in the beginning because (1) it is not yet feeling the negative consequences of having to compete among itself and (2) has not gotten into direct conflict with A yet over volume.

each other for resources, and B is playing a ‘short-term strategy’, the important question is whether or not B can completely annihilate the presence of A before the benefits of A’s ‘long-term strategy’ start kicking in.¹⁵ In section 4.6 this property will be used to argue that fitness is a time-dependent quantity, as whether or not a trait ‘benefits its bearer’ depends on the timescale over which it is evaluated.

The self-sacrifice of, for example, individual amoebae of the species *Dictyostelium discoideum* when forming fruiting bodies [173] is hard to understand from the perspective of individual fitness, in which case such self-sacrifice is categorically selected against, since it provides no immediate benefit to the individual. Patterns, however, exists on much longer timescales than the configurations of matter that realize it. The ‘fitness of a pattern’, therefore, depends on the timescale over which the increase in representation is evaluated. In the case of *Dictyostelium discoideum*, for example, Configurationalism would argue there must have been some critical point $t = t_c$ for which the fitness w_a of the self-sacrifice pattern and w_b of the self preserving pattern obeyed the following inequalities $w_a(t) > w_b(t) \mid t > t_c$, even though $w_a(t) < w_b(t) \mid t < t_c$. In other words, if a pattern has enough temporal propagation to make it past t_c it can ‘out-compete’ its rivals, even though, in the short term, it is ‘selected against’.

To make this idea somewhat less abstract, consider a decaying particle which has a 1% chance per unit time to decay. If one were to look over timescales of 0.001 units of time one would conclude that it were highly unlikely that the particle would decayed. If, on the other hand, one were to look over timescales of 1000 units of time, one would conclude that it were highly likely that the particle would decay. Similarly, it is possible for a trait to have a low fitness (i.e. be selected against) in the short term, yet have a high fitness (i.e. be selected for) in the long term (think Simpson’s paradox). The temporal propagation can be thought of as the number of micro-states of an evolutionary system’s macro-state that ‘make it past the critical point’. If one has enough systems and if the number of micro-states is not too low, there is a good chance a few systems will make it past the critical point and, if stable, dominate in representation at later times.

4.5 Spatial expansion and temporal propagation

To give some further context, Configurationalism allows one to think of evolution in terms of the *spatial expansion* and *temporal propagation* of patterns. Even though the struggle for existence was reformulated in terms of patterns competing for volumetric occupation, this formulation might underemphasize the temporal dimension and overemphasize the spatial dimension of the struggle for existence. Conquering volume is one thing, retaining volume another. If pattern A occupies 5 units of volume for 10 units of time and pattern B occupies 2 units of volume for 30 units of time, then pattern B has greater spatio-temporal extension than pattern A, even though pattern A, at its peak,

¹⁵Think of the rock-paper-scissor dynamics of rush-turtle-expand in real-time-strategy games. If a rush-player is, for some reason, unable to annihilate all the expand-player’s resource hubs before they break even on their initial resource investments, then the rush-player risks being swarmed by the expand-player’s increased unit production due to an overall stronger late-game economy.

had greater spatial extension.

Even though configurationalism has been introduced in terms of configurations of matter evolving through time, it would be more appropriate to conceive of physical reality in terms of a four dimensional spatio-temporal grid in which each grid unit is a tesseract with both spatial and temporal extension. To answer why one perceives more A than B not only depends on a particular distribution of configurations in the spatial dimension at a particular time, but also on the distribution of configurations in the temporal dimension. In other words, whether A is more abundant than B not only depends on *where* one looks, but also on *when* one looks.

4.6 Selection and fitness

From the perspective of Configurationalism, one can make sense of the spatial expansion and temporal propagation of patterns using the Darwinian vocabulary of natural selection and fitness. Ensemble-level fitness, using a bottom-up approach, can be conceived of as the time derivative of the weights $w(t)$ and $W(t)$, as these determine the ease of realization. If the weights increase, then the pattern is expected to appear in perception more often. Using a top-down approach, system-level fitness can be conceived of as the rate of change in a patterns volumetric occupation. In the case of ‘self-replicating patterns’ one can also employ fitness in terms of the rate of volumetric increase per unit volume occupied.¹⁶ An absolute measure of fitness also exists in terms of the time-integrated volumetric occupation of a pattern, which, over a given time period, expresses the total spatio-temporal extension of a pattern.

One advantage of thinking about fitness in terms of volume, is that different patterns can be compared. Cross-species fitness measurements can thus be conducted in a meaningful manner. If species A produces n offspring with average volumetric occupation \bar{V}_A and species B produces m offspring with average volumetric occupation \bar{V}_B , one can compare their fitness in terms of evaluating whether $n \times \bar{V}_A > m \times \bar{V}_B$. The advantage of this approach, is that it properly accounts for the differences in the reproductive rate and size of different species like ants and elephants.

Natural selection, using a bottom-up approach, can be conceived of as *the bias of nature* which expresses itself in terms of the temporal nature of micro-weights in configuration space. If the micro-configurations which realize pattern A have a much higher combined future macro-weight than the micro-configurations which realize pattern B, one can say there is ensemble-level selection of A over B. If one models an evolutionary system, one can think of ensemble-level selection in terms of the number micro-states which evolve such that after some time they realize a given macro-state. If, for example, an evolutionary system evolves such that the majority of its initial micro-states evolve such that, after a time period τ , their associated micro-configurations realize some pattern A, then pattern A is said to be selected for. Using a top-down approach, one can think of system-level selection as the differential spatial expansion and temporal propagation of

¹⁶Self-replicating patterns are patterns whose rate of volumetric increase scales with the number of patterns already realized.

patterns. If a pattern systematically increases in volumetric occupation over a prolonged period of time, there is system-level selection for said pattern over the time-period in question.

4.7 Chapter summary

In this chapter Configurationalism was introduced in terms of patterns competing for volumetric occupation. This notion was then refined by conceiving of evolution in terms of the differential spatial expansion and temporal propagation of patterns. The differential volumetric occupation of patterns, it was argued, was both due to physical as well as perceptual biases. In order to analyze the effect of physical biases on the perception of patterns, weighted configuration spaces were introduced in which multiple micro-configurations realized the same macro-configuration and, thus, the same pattern in perception.

Using a top-down as opposed to a bottom-up approach to analyzing the evolution of these weights, it was argued one could think of system-level fitness in terms of the rate of volumetric increase and system-level selection in terms of the systematic increase in volumetric occupation of a pattern. This top-down approach was based on the bottom-up approach in which ensemble-level fitness was conceived of in terms of the rate at which the weights of a macro-configuration realizing a pattern in perception increased and ensemble-level selection was conceived of in terms of the differential increase the macro-weights of these macro-states over time.

In the context of evolutionary modeling it was explained that ensemble-natural selection should be understood in terms of the number of initial micro-states which evolve such that they realize a given macro-state after some time period τ . If the majority of micro-states evolve such that after some time period τ they realize a given macro-state, then there is ensemble-level selection for said macro-state.

It was also noted that if one coarse-grained one's configuration space enough, one could obtain a trait space in which all the configurations which realize the same macro-configuration in terms of the distribution of traits in a population are grouped together. The next chapter further analyzes biological evolution from the perspective of these trait spaces.

Chapter 5

Configurational Evolutionary Theory

“I am a beacon of knowledge blazing out across a black sea of ignorance.”

– Carl, *The Invoker*

In the first section of this chapter I introduce a mathematical framework to study biological evolution in terms of trait spaces and show how trait spaces are a logical extension the configuration spaces discussed in chapter 4. This mathematical framework is introduced to make analysis of biological evolution more tractable, given that a configuration space approach at the level of atomic configurations would, practically speaking, be intractable and, furthermore, overly cumbersome with respect to the observables we actually care about when studying biological evolution. In the second section I show how Darwinian concepts like *natural selection* and *fitness* find intuitive use within this mathematical framework.

5.1 Evolutionary theory: A de-Darwinized description of biological evolution

Evolutionary theory can be formulated in a multitude of ways. Most of the time evolutionary theory is formulated using a Darwinian vocabulary, even if not explicitly Darwinian in interpretation. For the purposes of this section I will formulate evolutionary theory in terms of evolutionary trajectories through trait space, as these are a logical extension of the configuration spaces discussed in chapter 4 for size normalized trait carriers.¹

¹When studying trait frequencies within a population of individuals of the same species, one can safely assume that the trait carriers (e.g. organisms) are, on average, of similar size, thereby eliminating the need to track a pattern’s volumetric occupation, merely requiring one to track the pattern’s frequency of manifestation. When comparing ants and elephants, however, one must resort to a trait spaces analysis in which the volumetric occupation of the trait carriers in question, as opposed to the frequency, is tracked.

This chapter introduces the trait space formulation of evolutionary theory using the example of a population of organisms. In principle, however, the trait space formulation of evolutionary theory can be applied to any population of individuals, regardless of whether those individuals are genes, cells, organisms or even groups. Mathematically speaking, all these individuals are treated as trait carriers of differing dimensionalities. In the context of biological evolution, however, a population of organisms is an intuitive choice, as it is the quintessential exemplar of Darwinian evolutionary theory.

5.1.1 Trait space: The full information representation

Given a population P of N organisms with n distinct traits T_1, \dots, T_n each organism is represented as a point $O = (T_1, \dots, T_n)$ in which each trait T_1, \dots, T_n spans one of the dimensions of the n dimensional trait space of the organism. The population as a whole can then be represented as collection of points $P = \{O_1, \dots, O_N\} = \{(T_1^1, \dots, T_n^1), \dots, (T_1^N, \dots, T_n^N)\}$ in which each T_i^j represents the specific variation V of the trait T_i that organism j has.² The population can also be represented as a single point $P = (T_1^1, \dots, T_1^N, \dots, T_n^1, \dots, T_n^N)$ in an $N \times n$ dimensional trait space spanned by each T_i^j .

A given biological evolution, using this full information representation, is represented as a collection of points ‘moving’ through a trait space. The word ‘moving’ is in quotation marks, because individual points do not move. Each organism entering the population (i.e. being born) adds a new point to the collection while each organism leaving the population (i.e. dying) removes a point from the collection. Consequently it is the cluster as a whole that moves in terms of changes in the spread of the points and the average location of the points from one generation to the next.

Given that each organism entering or leaving the population adds a point to the collection, the population as a whole does not have a well defined trajectory through trait space, because each organism entering or leaving the population changes the dimensionality of P if represented as a single point.

Example

A population P of $N = 3$ individuals in which each organism O has two traits T_1 and T_2 . Trait T_1 has two discrete trait variations A and B and trait T_2 has continuous trait variations ranging from $-\infty$ to $+\infty$. Population P can be represented in trait space as either a collection of points $P = \{(A, 2), (A, 1), (B, 3)\}$ or as a single point $P = (A, A, B, 2, 1, 3)$. Figure 5.1 depicts P as a collection of points while figures 5.2 and 5.3 depict P as a single point. Given that P is six-dimensional, figure 5.2 only shows the location of P in the subspace of T_1 while figure 5.3 only shows the location of P in the subspace of T_2 .

5.1.2 Trait space: The reduced information representation

Even though the full information representation of a population’s evolutionary trajectory through trait space as a collection of organisms is, in principle, the

²I use curly brackets to denote collections

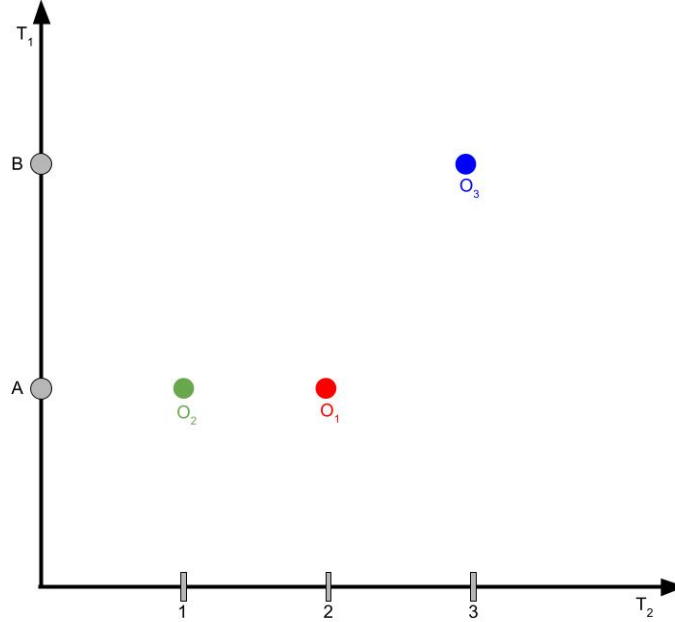


Figure 5.1: Trait space representation of $P = \{(A, 2), (A, 1), (B, 3)\}$. O_1 is represented in red, O_2 is represented in green and O_3 is represented in blue.

most accurate representation of a given biological evolution, it is not necessarily the most informative representation. Given that we only care about the evolution of the distribution of traits in a population, and not about which particular organism has which particular traits or which particular organism entered or left the population, a reduced information representation of the population in terms of the distribution and spread of traits within the population is much more insightful.³

A reduced information representation of population P also has the advantages that it preserves the dimensionality of the population when organisms enter and leave the population. This means that a reduced information representation of P , unlike in a full information representation, can be represented as an evolutionary trajectory (see figure 5.4). The point describing the state of P at any given moment in time can be understood as providing a *statistical summary* of the exact state of the population in terms of the distribution and spread of traits.

The distribution of a trait T_d with m discrete variations each possessed by N_m organisms in the population can be summarized as $\langle T_d \rangle = (\sigma_d, \frac{N_1}{N}, \dots, \frac{N_m}{N})$ with

$$\sigma_d = \sum_{i=1}^m \sqrt{\left(\frac{N_i - \sum_{j=1}^m \frac{N_j}{m}}{m} \right)^2}. \quad (5.1)$$

³It is a *reduced* information representation since it throws out the information about which particular organism has which particular trait.

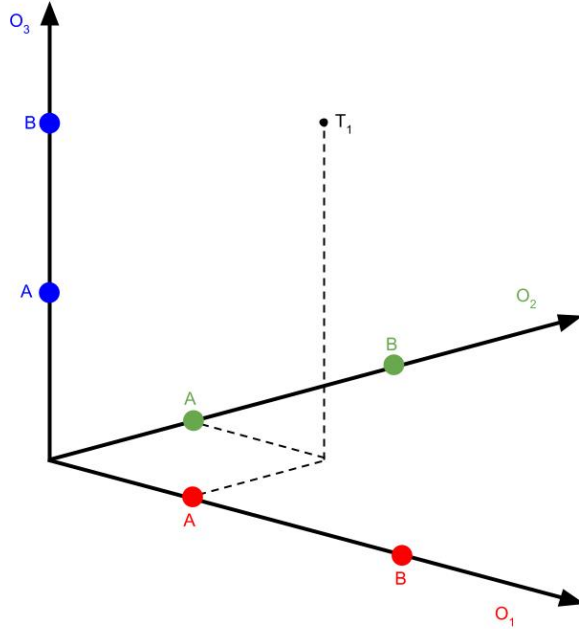


Figure 5.2: Trait space representation of the T_1 subspace of $P = (A, A, B, 2, 1, 3)$. The discrete states are mapped onto three continuous axis representing the distinct organisms O in population P .

The distribution of a trait T_c with continuous variations (e.g. ranging from $-\infty$ to ∞) can be summarized as $\langle T_c \rangle = (\sigma_c, \mu_c)$ with

$$\mu_c = \sum_{i=1}^N \frac{T_c^i}{N} \quad (5.2)$$

and

$$\sigma_c = \sum_{i=1}^N \sqrt{\left(\frac{T_c^i - \sum_{j=1}^N \frac{T_c^j}{N}}{N} \right)^2} \quad (5.3)$$

Where T_c^i is the trait of the i -th organism in a population of N organism. More generally μ represents the average and σ the spread of a trait. In the case of a continuous trait μ represents the average *value* of said trait while in the case of a discrete trait μ represents the average *number* of organisms per variation of said trait. The reduced information representation of a population P with N organisms O having n unique traits is then given by $\langle P \rangle = (\langle T_1 \rangle, \dots, \langle T_n \rangle)$.

Example

If the full information representation $P = (A, A, B, 2, 1, 3)$ its reduced information representation $\langle P \rangle = (\langle T_1 \rangle, \langle T_2 \rangle) = (0.5, \frac{2}{3}, \frac{1}{3}, 2, \frac{2}{3})$.⁴ This might not seem

⁴Given the fact that $(N_a/N) + (N_b/N)$ has to equal 1, one can, in principle, omitted either the 2/3 or the 1/3 in P 's reduced information representation without losing information.

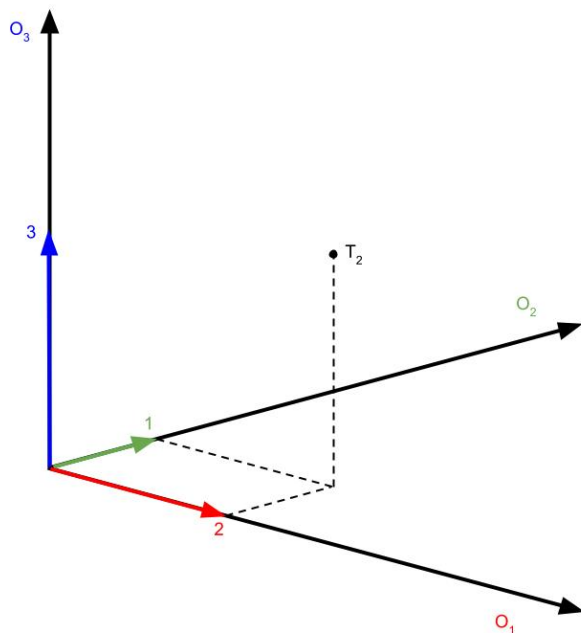


Figure 5.3: Trait space representation of the T_2 subspace of $P = (A, A, B, 2, 1, 3)$. Each axis represents the T_2 trait dimension of a single organism.

like much of an improvement, but while the dimensionality of P scales with N , the dimensionality of $\langle P \rangle$ does not, meaning that for $N \gg 1$ the tractability of $\langle P \rangle$ is much greater than that of P .⁵

5.1.3 Evolutionary forces in trait space

Within the reduced information representation of a population, each organism entering or leaving the population moves the population to a new location in trait space. One can define the effect of organisms entering or leaving the population (e.g. due to birth, death or migration) as an evolutionary force which pushes the population to a new location in trait space. The evolutionary force F exerted on a population due to an organism entering or leaving the population is defined as $F = \langle P_i \rangle - \langle P_f \rangle$ in which $\langle P_i \rangle$ is state of the population prior to the organism's entry or departure and $\langle P_f \rangle$ is the state of the population after the organism's entry or departure.⁶

The individual evolutionary forces exerted on a population due to organisms

⁵One could increase the tractability even more by replacing the $(N_1/N, \dots, N_m/N)$ component of discrete traits with a $\mu_d = \sum_{i=1}^N (N_i/m)$ component, though this would throw out a significant amount of already dimensionally invariant information. It is, therefore, that such practice is only advisable for discrete traits for which $m \gg 1$.

⁶It is important to note that the magnitude of the evolutionary force exerted on a population in trait space due to an organism entering or leaving the population *scales inversely with population size*. The magnitude of the evolutionary force exerted by an organism entering a population of $N = 4$ is much greater than an organism entering a population of $N = 1000$.

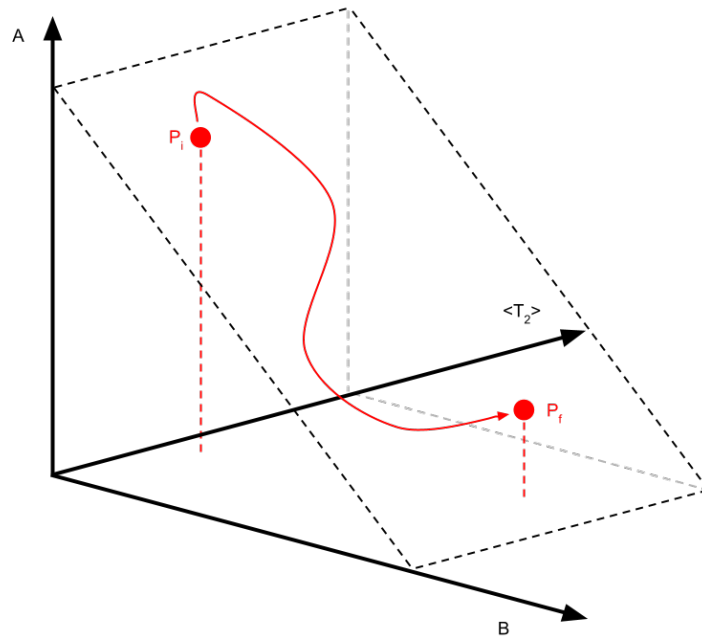


Figure 5.4: Visualization of what a potential evolutionary trajectory through a reduced trait space for population P might look like. The diagonal surface outlined with dashed lines contains all the points for which $\frac{N_a}{N} + \frac{N_b}{N} = 1$, which ensures that every organism in the population is either A or B and not something else. The point representing the population can only move over this surface.

entering or leaving the population are, however, of little interest. What is of interest, however, is the net evolutionary force exerted on a population due to all organisms entering or leaving the population due to a specific cause like, for example, predation (i.e. an environmental factor). Even though the individual evolutionary forces associated with predation can, in principle, point in any direction, their net effect can still move the population to a location in trait space with, for example, a higher average speed (see figure 5.5). I will use the term ‘minor’ evolutionary force to refer to the evolutionary forces exerted by individual organisms and ‘major’ evolutionary force to refer to the net effect of all minor evolutionary forces associated with a specific cause.

Two important remarks are in order. First, different major evolutionary forces can *overlap* because different causes can *coincide*. It is possible, for example, to attribute the death of a single organism to both illness and predation if the illness increases the chance of successful predation. Even though the sum of all minor evolutionary forces is, by definition, the net evolutionary force exerted on the population as a whole, the sum of all major evolutionary forces is not. There is a substantial risk that some minor evolutionary forces are not associated with any major evolutionary force, or with more than one major evolutionary force. Consequently, when explaining a given evolutionary trajectory in terms of major evolutionary forces, one must always be careful to emphasize that the

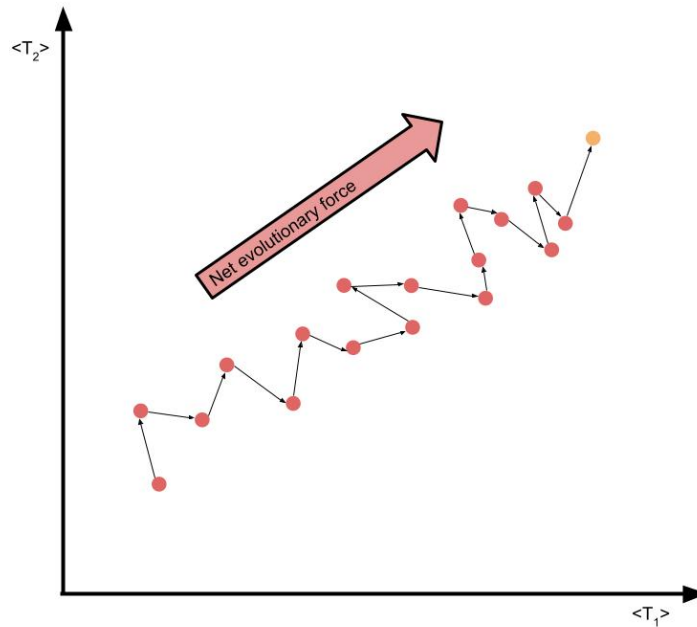


Figure 5.5: A visualization of how individual forces can point in a multitude of directions while still pushing the population in a net direction through trait space.

evolutionary trajectory as a whole cannot be explained in terms of some simple sum of major evolutionary forces.

Second, even if two major evolutionary forces do not overlap, this does not mean that they are independent. Even if the effect of predation and terminal illness might not overlap, this does not mean these two environmental factors are independent. If predators spread the terminal illness, then varying the degree of predation also varies the degree of terminal illness. Consequently, even if two major evolutionary forces do not overlap, one cannot infer that the causal contribution of these two major evolutionary forces is independent, even if they are separable within a given evolutionary trajectory.

Major evolutionary forces do, however, shed light on the relative importance of causes and their net effect on an evolutionary trajectory. Analyzing an evolutionary trajectory in terms of major evolutionary forces might, for example, reveal that the net direction of ‘death due to predation’ and ‘death due to fighting over females’ point in opposite directions. Where the major evolutionary force of predation might push a population in the direction of being less stocky and more agile, the major evolutionary force of fighting over females might push a population in the direction of being more stocky and less agile. If more organisms leave the population due to predation than fighting over females, then this helps make sense of the fact that the population as a whole evolved towards higher agility and less stockiness.

5.1.4 Micro-states and macro-states: The degree of convergence

Every macro-state describing an evolutionary system, and in particular a population's trait distribution, has multiple micro-states that realize said macro-state.⁷ The evolutionary trajectory of a population through trait space depends on the microstate that realizes said macro-state. The degree of convergence expresses the proportion of micro-states that realize a given macro-state whose evolutionary trajectory ends up in a specified region of trait space, usually defined in terms of some evolutionary outcome.

Figure 5.6, for example, shows the degree of convergence for the macro-states outside of the black circle in the top right corner to end up in one of the macro-states inside the black circle. The color on the heat map indicates the degree to which the micro-states of the macro-state outside of the black circle yield an evolutionary trajectory whose evolutionary outcome realizes one of the macro-states within the black circle. In the scenario shown, the higher $\langle T_1 \rangle$ and $\langle T_2 \rangle$ the more likely the macro-state is to end up in one of the macro-states within the black circle.

To further visualize the degree of convergence, consider figure 5.7 which shows the different types of evolutionary trajectories for the macro-state represented by the red dot. The majority of the micro-states of said macro-state, say 98%, will evolve such that they yield an evolutionary trajectory which stays confined within the blue area and ends up in one of the macro-states within the orange circle. Such evolutionary trajectories will look similar to that represented by the blue arrow. A small number of micro-states, say 1.5%, will evolve such that they yield an evolutionary trajectory which does not stay confined within the blue area, but which does end up in the orange circle. Such evolutionary trajectories will look similar to that represented by the purple arrow. The degree of convergence from the red macro-state to one of the macro-states within the orange circle is 99.5%. A very smaller number of micro-states, say 0.5%, evolve such that they yield an evolutionary trajectories that does not end up in one of the macro-states within the orange circle. Such an evolutionary trajectory will look similar to that represented by the green arrow.

The degree of convergence can be used to make informed predictions about the future state of a population's trait distribution while also allowing for a certain degree of deviation from expectation in terms of small percentage of non-representative micro-states that evolve such that they yield evolutionary trajectories that do not converge to an evolutionary outcome that the majority of micro-states that realize a given macro-state converge to.

⁷It is important to note that the micro-states discussed in the context of biological evolution are not necessarily at the level of atomic-configuration. See appendix A.7 for more on the relation between micro- and macro-states with respect to the 'true-states' of a system. Roughly speaking, micro-states in this context are state that describe the evolution of a population at the level of the individuals and their interactions with the environment (and each other) while macro-states are states that describe the evolution of a population at the level of the population as a whole and its interaction with the environment as a whole. In other words, it is the difference between knowing the average effect of predation on a population's trait distribution, and knowing which particular prey will be caught by which particular predator.

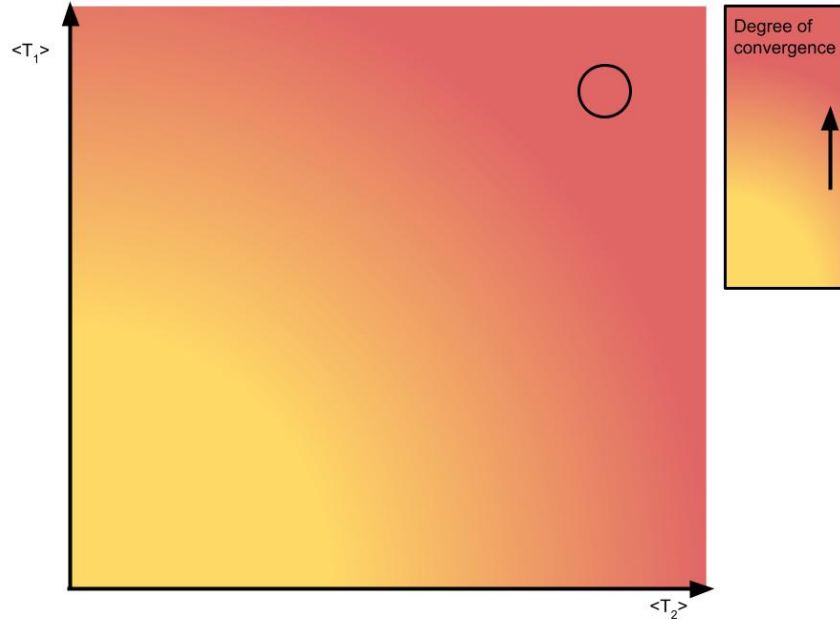


Figure 5.6: A heat map representation of the degree of convergence for the macro-states outside the black circle to end up in a macro-state within the black circle after some time t .

Where do deviations come from?

In general we do not know the exact state of an evolutionary system. We do not know, for example, which predator will target which prey, we do not know which individual has which trait profile, etc. This lack of knowledge needs to be accounted for. In theory, if everything were known, no deviation from expectation would ever occur.⁸ In practice, however, we either do not care or physically cannot determine the exact state of an evolutionary system. Thus, when provided with the state of an evolutionary system, one is usually provide a macro-state S_M which can be realized by many micro-states S_m .

Deviation from expectation can now arise from two sources. The first source is uncertainty about the exact macro-state S_M , the second source is uncertainty about the exact microstate S_m realizing a given macro-state S_M . One can, however, either empirically or conceptually, analyze a given evolutionary system to determine or approximate the degree of convergence to some final outcome under the influence of some environmental factor(s). Given the two stage predation discussed in section 3.5.1, for example, one can determine that $x\%$ of the initial micro-states evolve such that in the final macro-state they realize the average speed of organisms has increased. This number $x\%$ expresses the degree of convergence, which is a measure of the ‘strength’ of a given environmental factor,

⁸Similarly, if one knows the initial configuration of a system (including state descriptors), and the laws of physics, the systems future states are fully determined.

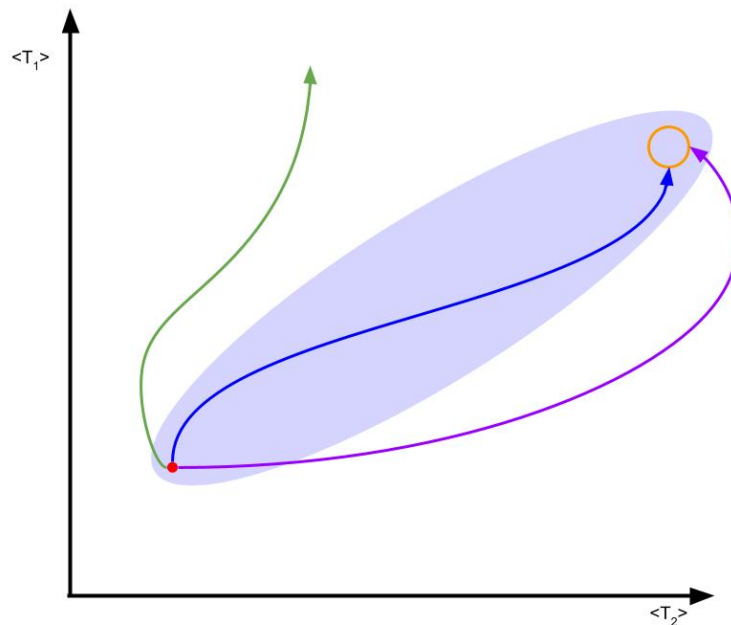


Figure 5.7: The different types of evolutionary trajectories possible based on the microstate degeneracy of an evolutionary systems macro-state.

in relation to the rest of the environment, to bring about a certain outcome given some wide range of initial conditions.

Example

One source of deviation from expectation is uncertainty about the exact distribution of traits. For example, given some macro-state S_M given by $\langle P_M \rangle = (\langle T_A \rangle, \langle T_B \rangle)$ in which T_A can be either A_1 or A_2 and T_B can be either B_1 or B_2 the macro-state $\langle P_M \rangle = (A_1, B_2)$ realized by the multiple micro-states $\langle P_m \rangle = (A_1B_1, A_1B_2, A_2B_1, A_2B_2)$. The macro-state $\langle P_M \rangle = (0.5, 0.5)$, for example, can be realized by both $\langle P_m \rangle = (0.45, 0.05, 0.05, 0.45)$ as well as $\langle P_m \rangle = (0.25, 0.25, 0.25, 0.25)$. Consequently, if fitness values are frequency dependent, ignorance of the exact micro-state $\langle P_m \rangle$ which realizes the macro-state $\langle P_M \rangle$ can result in deviations from the expected outcome.

5.1.5 Evolutionary theory and empirical research

Based on the evolutionary theory formulated, basic predictions about the direction and rate of a given population's evolutionary trajectory can be made. The most basic type of prediction is extrapolation of the evolutionary trajectory based on historic data. In other words, based on the past rate and direction of the population through trait space, predictions about its future rate and direction are made.

A more advanced, though potentially also more speculative, type of prediction

can be made by analyzing how a the evolutionary trajectory of a sub population changes as a result of varying a given environmental factor (e.g. number of trees per square meter). If one assumes that the sub-population and its environment are representative of the population and its environment as a whole, it is possible to make predictions about the evolutionary trajectory of the population as a whole based on the sub-population's response to changes in the environment.

If environmental factors cannot be manipulated directly, it is also possible to do sub-population analysis if there exist distinct sub-environments. If for example, variation in the environment strongly correlates to variation in the sub-population's trait distribution, one might infer that these variations in trait distribution are due to the variation in the environment. One can then make predictions about the consequences of global changes to the environment based on observation of local variation in the environment and its correlation to local variations in trait distribution of the population.

5.2 Configurational evolutionary theory: A re-Darwinized description of biological evolution

From the perspective of biological configurationalism there are two levels at which one can understand natural selection: a system-level and an ensemble-level. At the system-level natural selection is understood in terms of the *shape* of a population's evolutionary trajectory. At the ensemble-level natural selection is understood in terms of the *degree of convergence* of an environment or environmental factor. At the system-level one can say an evolutionary trajectory *exhibits* natural selection (or drift) while at the ensemble-level one can say an evolutionary trajectory is an *expression* of natural selection (or drift).

5.2.1 System-level natural selection as the shape of an evolutionary trajectory

At the system-level natural selection can be understood in terms of the *shape* of a population's evolutionary trajectory. If the evolutionary trajectory exhibits *directionality* it is said to exhibit natural selection. System-level natural selection is understood as solely in terms of the *process* of differential survival and reproduction. Thus, when a population's evolutionary trajectory shows a net movement through trait space, or a significant reduction or stabilization in trait spread, it is said to exhibit natural selection (see figure 5.8).

The justification for this definition of system-level natural selection is that if there were no differential survival and reproduction based on an individual's trait profile, the population would not move through trait space. Furthermore, if new trait variations entered the population without being filtered out by natural selection, the population's trait spread would increase. Thus, if a population's evolutionary trajectory exhibits *no* movement *and* an increase in treat spread, no system-level natural selection is occurring.

From the perspective of system-level natural selection it is appropriate to say that if a trait systematically increases in representation within a population,

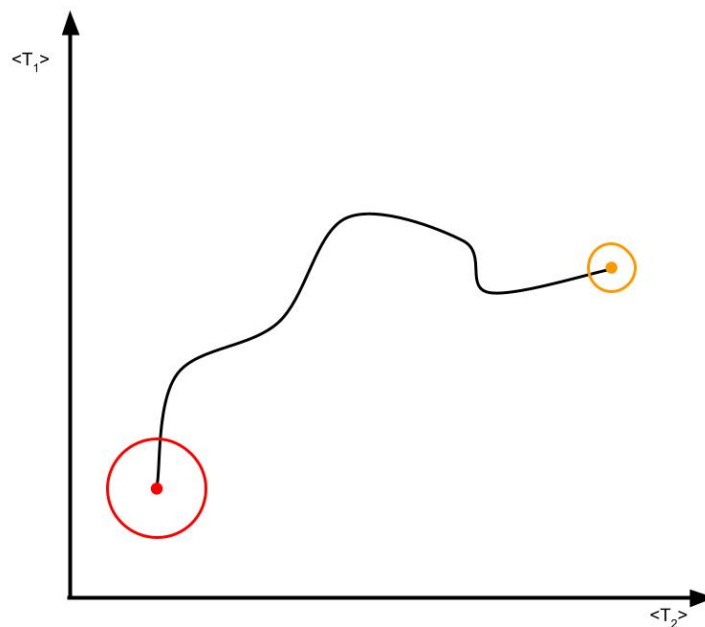


Figure 5.8: This evolutionary trajectory exhibits natural selection: It shows both significant movement through trait space, going from red to orange, and it shows a reduction in the spread of traits depicted by the fact that the radius of the orange circle is smaller than the red circle.

that there is *selection for* said trait. Equally, if a trait systematically does not decrease in representation while new traits that enter the population do, it is also appropriate to say there is *selection for* the trait profiles already in the population.⁹

5.2.2 Ensemble-level natural selection as the degree of convergence

The problem with system-level natural selection, is that it cannot distinguish ‘luck’ from ‘fate’. System-level natural selection only analyzes selection in terms of whether the *outcome* is right, but not in terms of whether the *reason* is right. System-level natural selection does not differentiate between running speed increasing because predators discriminate between prey based on their ability to run fast and lightning strikes that ‘just so happen’ to only hit the slow prey.

⁹The distinction between *selection for* and *selection of* is largely artificial from the perspective of configurationalism, since it does not accept the legitimacy of functional analysis to determine if a trait ‘benefited the organism’. Genetic linking, for example, is nothing but selection at the level of the gene. *Selection of* is only with respect to some specific environmental factor like, for example, predation: The environment as a whole still selects *for* the genetically linked trait, even if one believes the trait does not benefit the organisms that have it.

Ensemble-level natural selection can make this distinction, as it does not analyze natural selection in terms of the shape of a population’s evolutionary trajectory, but in terms of the degree of convergence of an evolutionary system’s macro-state. If an initial macro-state S_M^a of a given evolutionary system has a high degree of convergence to evolve towards another macro-state S_M^b , then one can say there is selection for S_M^b , even if it turns out that the initial micro-state $S_m^{a_i}$ that realized S_M^a evolved into a micro-state $S_m^{c_k}$ which realized a different macro-state S_M^c as opposed to a micro-state $S_m^{b_j}$ which realizes S_M^b .

In principle such an analysis would require a full analysis of the systems weighted configuration space (including the underlying state space given that there are dynamical biases), but one can also *approximate* the result of such an analysis either by performing a coarse grained bottom-up analysis or a top-down analysis, given that a full analysis of an evolutionary system’s state space is, in general, unfeasible.

Using a coarse grained bottom-up analysis one would make a simplified evolutionary model of the evolutionary system, which includes both the population *and* its interaction with the environment and determine all the possible initial micro-states that realize a known macro-state of the population in the past. It would then determine the number of initial micro-states which evolved such that they yielded the obtained outcome.¹⁰ If high enough, one would determine the outcome was *representative* and therefore an expression of natural selection. If the number were low, one would determine the outcome was *unrepresentative* and therefore an expression of drift.

Using a top-down analysis one would perform a *sub-sample analysis* on the evolutionary trajectory in order to determine if the global trend in the system were reflected by its local trends. This sub-sampling would be achieved by both partitioning in space and in time, in other words, by partitioning the population into random sub-populations and by partitioning the evolutionary trajectory as a whole into smaller evolutionary sub-trajectories. By then studying the effects of the major evolutionary forces, one can determine whether they are both *consistent* in their application and in their effect. If one does not find any ‘deviant behavior’ of the major evolutionary forces using this sub-sample analysis, one can be *reasonably* certain that the shape of the evolutionary trajectory is representative and thus an expression of the natural selection. In other words, if one were to encounter two evolutionary trajectories, represented in blue and in green in figure 5.9, one would be able to say that the blue one is an expression of natural selection while the green one is not.

To elaborate on this top-down analysis using coin flips, what one is effectively doing, after having flipped a collection of 1000 coins, is to partition the sequence of flips into sub-samples and analyze whether, within the sub-sample, the global trend also held. If, for example, the global trend were 70:30, but locally (i.e. on intervals of 30 coins) one would not find this same 70:30 behavior, but instead an alternating 90:10 and 50:50, one might infer that the global outcome is not representative of the actual underlying dynamics and, hence, not ‘for the right reasons’ in the sense that it was because the coins were individually close to

¹⁰The term number should be understood in a relative sense. In other words, it is not about the absolute number of states, but about the relative number (i.e. the proportion) of states.

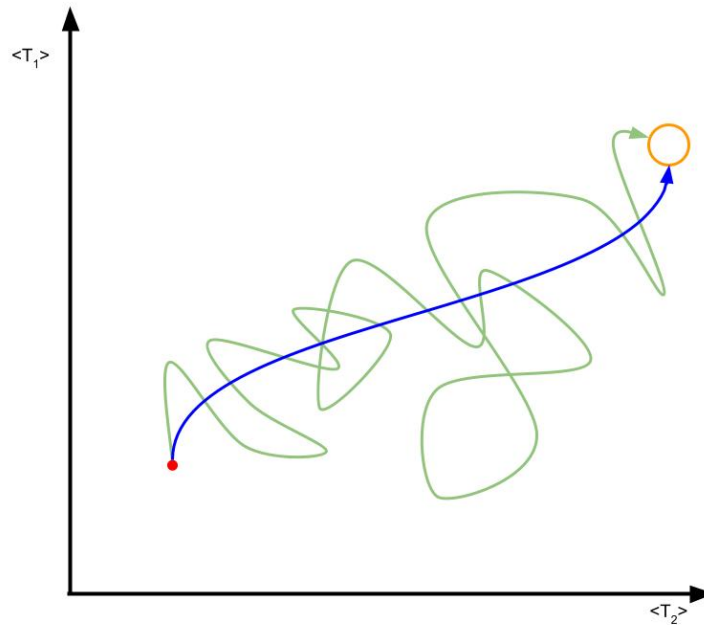


Figure 5.9: Both the green and the blue evolutionary trajectory produce the same ‘correct’ outcome, but whereas the blue evolutionary trajectory’s sub-trajectories are reflective of its global trajectory, the green evolutionary trajectory’s sub-trajectories are not. This might make one suspect that, with respect to the representative and stable environmental factors, unrepresentative and perturbing environmental factors ‘just so happened’ to produce the right outcome for the green population, even if the shape as a whole is representative.

70:30.

If, for example, one studies a population’s evolutionary trajectory for an extended period of time, and sees that over that period of time it has systematically moved in the direction of increased average running speed, then one can be reasonably certain that the environment imposes a high degree of convergence when it comes to that final outcome. In other words, given a large ensemble of evolutionary system with populations described by the same general macro-state and in the presence of the same general environmental factors, one would expect the majority of those populations to also evolve in such a manner that, over time, the average running speed increases.

Especially if the population is large and the time frame over which a trend holds extensive, one can have a high degree of certainty that the environment, in general, has a high degree of convergence for a certain evolutionary outcome and, thus, that there is *ensemble-level selection for* a certain evolutionary outcome. Similar to how one’s certainty about whether a coin is fair increases with the number of times a coin is flipped.

5.2.3 Random drift as deviation from expectation due to ignorance

If one were able to exactly specify an evolutionary system's micro-state one would, in principle, be able to predict each and every evolutionary outcome at every possible time. In practice, however, one only knows an evolutionary system's macro-state. One might know the general distribution and spread of traits, one might know the general environmental factors present and perhaps one even knows how, in general, these environmental factors interact with the population, but one does not know the exact sequence of events that will produce the final outcome based on the initial micro-state of the evolutionary system.

Due to this ignorance about the exact micro-state that realizes the macro-state describing a population, one cannot have absolute certainty about the evolutionary trajectory a population is going to take through trait space. In particular, if it so happens that one's macro-state is realized by an *unrepresentative* micro-state (i.e. one that results in an evolutionary trajectory not representative of those realized by the majority of micro-states that realize the same macro-state), one might obtain an evolutionary outcome vastly different than expected. Such deviations from expectation due to having one's macro-state realized by an unrepresentative micro-state are an expression of *drift*. Drift is the inverse of natural selection, in the sense that, if an evolutionary trajectory is an expression of natural selection it cannot also be an expression of drift. It is possible, however, for an evolutionary trajectory to *exhibit* natural selection even though it is an *expression* of drift. The green arrow in figure 5.7, for example, exhibits natural selection while also being an expression of drift.

Generally speaking, in large populations living in a stable environment whose environmental factors impose a high degree of convergence on an evolutionary system's macro-states, the probability that one obtains a drift-trajectory is low. In smaller populations living in turbulent environments whose stable environmental factors impose a low degree of convergence on an evolutionary system's macro-state, the probability that one obtains a drift trajectory is high. To draw the parallel to the coin flip analogy: the more often a coin is flipped the more likely the outcome distribution is going to be representative of the coin's fairness.

5.2.4 Fitness as a growth rate

Like natural selection and drift, fitness has both an ensemble-level and a system-level interpretation, similar to what was discussed in section 4.6. At the system-level fitness can be understood as the rate at which a trait increases in representation or, more technically formulated, as the partial derivative of an evolutionary trajectory through a traits subspace with respect to time. At the ensemble-level fitness can be understood as the increase in the degree of convergence as the time period over which it is analyzed increases.¹¹

The future representation of a trait can be *approximated* by extrapolating based on the past rate of increase (i.e. system-level fitness). Fitness in practice, therefore, is a way to quantify one's expectation about the future representation

¹¹The degree of convergence over a given time period is not itself time-dependent.

of traits. Both system-level fitness and ensemble-level fitness are time-dependent quantities. Whether or not pattern A is fitter than pattern B, or whether pattern A is selected over pattern B, therefore, depend on the timescale over which the representation of these patterns is analyzed.

Notice also how fitness is associated with traits and trait profiles and not with individuals. Even though it might very well be true that there are genuine differences in the ability of individuals to survive and reproduce based on their trait profile, evolution does not care about such matters. The only thing that matters is whether a trait increases or decreases in representation. Whether this is achieved by ‘aiding the individual’ or by ‘subjugating the individual’ is of no concern with respect to the evolutionary outcome that obtains.

5.3 Chapter summary

The biological evolution of a population P of N individuals with n distinct traits can be represented as a point in a $N \times n$ dimensional trait space. By coarse grinding the configuration spaces introduced in chapter 4 to trait spaces, it was shown that the evolution of a population’s trait distribution could be represented as an evolutionary trajectory through the population’s corresponding trait space.

Based on this trait space representation it was noted that there were two types of natural selection: system-level natural selection and ensemble-level natural selection. System-level natural selection is based on the shape of a population’s evolutionary trajectory while ensemble-level natural selection is based on the degree of convergence of an evolutionary system in terms of ‘how likely’ it was to produce a given evolutionary outcome. Similarly drift could be understood as deviation from expectation due to the micro-state of one’s evolutionary system being unrepresentative at the ensemble-level while, at the system-level, ensemble-level drift could be identified in terms of the significant deviation of sub sample trends with respect to the overall sample trend. Fitness also had a system-level and ensemble-level understanding. At the ensemble-level fitness could be understood as rate at which the degree of convergence increases as one extends the time period over which representation is evaluated and at the system-level fitness could be understood as the rate at which a trait or trait profile increases in representation within a population.

Chapter 6

Philosophical Reflections

“So begins a new age of knowledge.”

– Carl, *The Invoker*

At the end of chapter 3 three topics within the philosophy of evolutionary biology were discussed: the nature of selection, the unit of selection and the nature of fitness. This chapter revisits those problems and makes sense of them from the perspective of Configurationalism. It also briefly highlights some potential philosophical implications one might derive from the mathematical structure of trait space.

6.1 On the nature of selection

6.1.1 Process vs outcome

The debate about whether natural selection should be understood as a *process* or as a *outcome*, it was argued, mainly pertained to whether one should understand natural selection in terms of the outcome being right or in terms of the reasons being right. The distinction between system-level selection and ensemble-level selection developed in chapter 5 solves this problem.

System-level selection is about obtaining the *right outcome* in terms of there being a process of differential survival and reproduction which results in some traits increasing in representation while others decrease in representation, regardless of the reasons why such traits increase or decrease in representation.

Ensemble-level selection is about being due to the *right reasons* in terms of the process of differential survival and reproduction being representative in terms of the final outcome obtained, the major evolutionary forces that pushed the population there and the general shape of the evolutionary trajectory.¹

From the perspective of Configurationalism, therefore, there is no problem, because natural selection is not understood as a singular concept, but rather,

¹The representativeness of the shape of an evolutionary trajectory is not the same as whether or not its shape exhibits natural selection

a concept which embodies different meanings at the system-level and at the ensemble-level. Looking at figure 5.7, for example, Configurationalism deems it appropriate to consider the green evolutionary trajectory as *exhibiting* natural selection, because its shape is one associated with the process of differential survival and reproduction, even though it is not an *expression* of natural selection, because the micro-state that realized this evolutionary trajectory is unrepresentative of the evolutionary trajectory realized by the majority of micro-states that realized the same macro-state. In other words, the outcome of the trajectory at the system-level is ‘right’, but the reasons for the outcome being right at the ensemble-level are ‘wrong’.

6.1.2 Cause vs form

Natural selection and Configurationalism

From the definition of evolution given in section 2.1 and the manner in which both system-level and ensemble-level natural selection is defined, it follows that natural selection cannot cause evolution. If natural selection is conceived of as the process of differential survival and reproduction, then it necessarily is a form of evolution, since evolution was defined as any change in a population’s trait distribution.² Given that any individual entering or leaving the population ever so slightly changes the distribution of traits within a population, it follows that the process of natural selection is indistinguishable from the process of evolution. There might be evolution without natural selection, but there cannot be natural selection without evolution. System-level selection, therefore, is not a cause of evolution, but a form of evolution.

If natural selection is conceived of as the degree of convergence of an environment, it is neither a form nor a cause of evolution. Given the fact ensemble-level selection is an *epistemic tool* to account for our *ignorance* about an evolutionary system’s micro-state, and not a physical process like system-level natural selection, it fundamentally cannot cause evolution, unless one intends to attribute causal powers to ignorance. Saying ensemble-level selection causes evolution is similar in nature to claiming the second law of thermodynamics causes heat to flow from hot to cold regions. Both might be ‘true’ in the sense that they accurately *describes* physical reality, but they can hardly be said to cause the physical outcomes they predict.³

Natural selection and Darwinism

One might object, however, that natural selection and evolution as defined by Configurationalism are different from natural selection and evolution as defined by Darwinism. To eliminate any form of doubt as to whether or not natural

²One should understand the concept of ‘form’, as it is used in this context, in the sense that one can say that ‘swimming is a *form* of exerciser’, that ‘a bus is a *form* of transportation’ and that ‘ice is a *form* of water’. To say that natural selection is a form of evolution is to say it is a mode of evolution, a way in which evolution unfolds, that is, something that cannot be seen as separate or distinct from the process of evolution itself.

³In principle one could claim the second law of thermodynamics to be causal, but it would be the equivalent of claiming action to be causal. Such a view would be thoroughly teleological in the sense that events happen, not because of the past made them happen, but because they were required to happen.

selection is a cause or a form of evolution, this section considers Sober's formulation of Darwinian evolutionary theory as outlined in his *The Nature of Selection: Evolutionary Theory in Philosophical Focus* and shows that, even from within this Darwinian framework, the claim that natural selection causes evolution is misguided.

Sober defines Darwinian evolutionary theory as a theory of forces [94, p. 31], regarding the causal nature of selection he writes that "natural selection is one of the causes of evolution, but an organism's fitness is not a cause of its survival and reproductive success" [94, p. 85]. Later he asserts this characterization again when he writes that "natural selection—that is, selection for characteristics—is one of the causes of evolution" [94, p. 101] and that "natural selection is a deterministic evolutionary force" [94, p. 111].

But how does Sober define evolution and how should one understand evolutionary forces? Regarding the first Sober writes that "the definition of evolution as change in gene frequencies is a useful rule of thumb, not a hard-and-fast principle" [94, p. 31]. Regarding the second Sober writes that:

In evolutionary theory, the forces of mutation, migration, selection, and drift constitute causes that propel a population through a sequence of gene frequencies. To identify the causes of the current state [...] requires describing which evolutionary forces impinged. [94, p. 141]

In summary, Sober believes natural selection is an evolutionary force, that evolutionary forces cause changes in gene-frequencies and that changes in gene-frequencies constitute evolution.

The first objection follows from his definition of evolutionary theory as a theory of forces. The idea that the force of natural selection can be opposed by the force of drift appears cogent, but how come the forces of mutation and migration can oppose the force of natural selection? Are mutation and migration not also expressions of or subjected to natural selection? Suppose there is a mutation bias, is this not natural selection favoring one mutation over another? Suppose the ability to migration depends on an individual's trait profile, is this not an expression of natural selection?⁴

The second objection follows from the fact that, even if natural selection and drift are causes, they have not added scientific value. Using the criteria of section 2.5 it is possible to identify mutation and migration as causes of evolution, as they can be identified prior to and independently of their effect on a population's trait distribution. The evolutionary forces of natural selection and drift, on the other hand, are purely defined in terms of their effect on a population's trait distribution and, therefore, lack added scientific value.

In other words, even if natural selection were to be a 'true cause of evolution' it would lack any form of *physical instantiation* and be completely *ex post facto* in nature. Would it be wrong to claim natural selection, thus defined, to be a cause of evolution? In principle, no. But that does not mean there is any added

⁴For an argument against natural selection as an evolutionary force based on the reductive nature of forces and the incompatibility of evolutionary interests at different levels of biological organization, see [174].

scientific value to incorporating such a definition of natural selection into our best scientific theory about biological evolution.

Defining natural selection this way is the equivalent of claiming the red car won the race because it was faster, which on its own is already a rather trivially explanation, but then also basing one's claim that the red car was faster on the result of the race itself. Even if not false, without independent means to verify such claims prior to and independently of the results of the race and without the ability to reduce the differential fastness to differences in, for example, aerodynamics and engine design, it just is not particularly insightful to claim that the red car being faster caused it to win the race.

Natural selection and evolutionary outcomes

Even though system-level natural selection does not cause evolution, it does cause evolutionary outcomes. It might be inappropriate to consider the process of differential survival and reproduction to cause evolution, i.e. changes in gene frequencies, it most certainly is not inappropriate to consider this process to cause evolutionary outcomes. To claim the eye is a product of natural selection, that is, of a long sequence of individuals entering and leaving the population in a *biased manner* is most certainly correct. More over, without individuals entering and leaving the population in a biased manner, the eye would not have evolved. In other words, natural selection most certainly causes evolutionary outcomes such as the existence of eyes, wings, and other traits.

6.2 On the unit of selection

Given that natural selection does not cause evolution and, hence, is not an evolutionary force 'acting on stuff', it makes little to no sense to ask what the unit is on which selection acts.⁵ Furthermore, given the fact that Configurationalism rejects the legitimacy of biological design, the question of for whose (ultimate) benefit adaptations evolve and accumulate also makes no sense. In short, even though the unit of selection debate has been a major topic in the philosophy of (Darwinian) evolutionary biology, it is of no interest to the Configuralist other than for the heuristic purpose of making a given evolutionary trajectory intelligible in terms of how certain traits 'benefit' the individual.

From the Configuralist perspective, patterns (e.g. organism and their DNA) propagate as a whole, including their cultural variations and constructed niches. Configurationalism, therefore, provides a basic degree of support for developing an extended evolutionary synthesis or, at the very least, rejecting the Neo-Darwinist idea that the gene is the central unit of evolution as discussed in 3.5.2.

⁵Keep in mind, evolutionary forces, as defined in chapter 5 act on populations by introducing or eliminating (i.e. selecting) individuals, though technically speaking, evolutionary forces act on trait carriers.

6.3 On the nature of fitness

6.3.1 Context transitivity and the tautological nature of fitness

Before arguing that fitness is a growth rate as opposed to a disposition, I should address whether the concept of fitness is cogent to begin with. In other words, is ‘survival of the fittest’ a tautological or trivial claim about reality, or a deep insight? To answer this question, let us turn to physics first and analyze the relation between an body’s gravitational mass and the gravitational force it exerts on other bodies. Here the same problem appears in terms of ‘bodies with the greatest gravitational mass exert the greatest gravitational force’ and ‘bodies which exert the greatest gravitational mass have the greatest gravitational mass’. This definition of mass is, in a sense, just as problematic as the definition of fitness, yet there does appear to be an important difference in terms of *context transitivity*.

Whereas mass and its effect are, generally speaking, context invariant, fitness is not. In other words, mass, unlike fitness, is context transitive. If $m_a = 2m_b$ and $m_b = 3m_c$ then it also follows that $m_a = 6m_c$. Fitness, on the other hand, can be such that $w_a = 2w_b$ and $w_b = 3w_c$ yet $w_a = 0.5w_c$. Fitness values are like rock-paper-scissors. Just because organism A outcompetes organism B in environment E and organism B outcompetes organism C in environment E, does not mean that organism A outcompetes organism C in environment E. It seems to me that this lack of context transitivity of fitness values is what makes their added scientific value questionable, not that they are defined in a ‘circular manner’, but because fitness values, if defined in terms of survival and reproduction, have very little predictive value outside of the specific context in which they were assigned.

6.3.2 Fitness, but of whom?

Having established that, in principle, the tautological or trivial nature of fitness is not in and of itself a problem, one might inquire how to define and operationalize fitness within the context of evolutionary theory. If one were to read Sober’s *The Nature of Selection: Evolutionary Theory in Philosophical Focus* or Ridley’s undergraduate textbook *Evolution* one might find the idea that fitness represents the degree to which an organism has adapted to their environment an intuitive definition and, furthermore, think that measuring fitness in terms of survival and reproductive success is a proper operationalization of said definition.

Sober, for example, writes that “evolution predicted by differences in Darwinian fitness is driven by differences in viability and fertility among organisms” [94, p. 46], that to “ascribe a level of fitness to an organism is to say what its chances of surviving and reproducing are” [94, p. 47] and that “fitness is a probabilistic disposition (a propensity) to survive and be reproductively successful” [94, p. 75]. And Ridley writes that

In evolutionary theory, fitness is a technical term, meaning the average number of offspring left by an individual relative to the number

of offspring left by an average member of the population. This condition therefore means that individuals in the population with some characters must be more likely to reproduce (i.e., have higher fitness) than others. [30, p. 74]

The first problem one will encounter when using this definition, is that sex ratios will be incomprehensible. How come that most individuals of a sexually reproducing species produce an equal number of males and females? In order to solve this problem one must, as Fisher did, not analyze the problem in terms of offspring, but in terms of grand-offspring [175, p. 141-143]. In other words, fitness differences need to be expressed in terms of the survival and reproduction not of one, but of two generations. But this begs the question. Why not analyze in terms of three, four, five, or, any other number of generations? By accepting that evolution does not necessarily tend to the *immediate* evolutionary success of an individual in a *single* generation, one accepts, willingly or not, that evolutionary theory is about *patterns* and their temporal propagation and not *individuals* and their number of offspring. In other words, Fisher's explanation of sex ratios is an example of a phenomenon that, strictly speaking, cannot be understood from a Darwinian perspective.⁶

Evolution, is not about how much offspring an individual can produce, nor about how well an individual can outrun predators. Evolution is about whether a pattern, for example a trait profile, increases or decreases in representation. Dawkins is interesting in this respect, since he writes that:

The life of any one physical DNA molecule is quite short - perhaps a matter of months, certainly not more than one lifetime. But a DNA molecule could theoretically live on in the form of copies of itself for a hundred million years." [103, p. 55]

Notice how it is not the individual DNA molecules but their code that lives on and evolves. But what is a 'genetic code' other than a pattern in the ones and zeroes of life? Also notice the artificial distinction between the gene as the unit of selection and the individual as the unit of selection. If it is not about individual DNA molecules, but their code, why can evolution not also be understood as not being about individual organisms, but their species? ⁷

Even though the Configurationalist formulation of evolutionary theory in terms of patterns as opposed to individuals might be perceived as counter intuitive at face value, I believe it is quite similar to many of the models already used in evolutionary biology to explain the existence of, for example, altruism [176, 177]. The fact these models actually concern patterns, as opposed to individuals, is obfuscated by the Darwinian vocabulary used to communicate them, but the

⁶Obviously did not prevent evolutionary biologists from using a Darwinian vocabulary to describe and 'make sense of' the phenomena, even if, in doing so, they fragmented Darwinism's conceptual unity and internal consistency. Then again, sometimes it is better to have a interpretation, however flawed, than *no* interpretation. A sentiment I believe most quantum physicists will wholeheartedly agree with.

⁷One of the reasons Dawkins might not accept this line of argument, is because he believes the unit of selection should be a replicator with sufficient longevity, fecundity and copying-fidelity [103, p. 56]. But why does Dawkins believe that organisms do not exhibit sufficient longevity, fecundity and copying-fidelity? What, using the criteria of longevity, fecundity and copying-fidelity, privileges the gene over the organism?

move from describing the evolution of altruism in terms of within and between group selection to short-term and long-term selection is, to my best knowledge, but a minor reinterpretation of the mathematical framework employed.⁸

6.3.3 So individual fitness is a lie?

It might appear from the discussion thus far that, from a Configurationalist perspective, the idea that some individuals are more ‘adapted’ to their environment is wrong and that, therefore, thinking of fitness in terms of an individual’s disposition to survive and reproduce is also wrong. This, however, would be an incorrect representation of the Configurationalist’s objection. It might very well be true that different individuals differ in their ability to survive and reproduce. The point the Configurationalist makes, however, is that from the perspective of evolution itself, the ability of individual’s to survive and reproduce is only of secondary importance. This is not a new idea, in *The Trials of Life: Natural Selection and Random Drift*, for example, Walsh, Lewins and Ariew already argue that differences in individual fitness alone are not enough to bring about changes in gene frequencies [112]. An individual’s ability to survive and reproduce is only important *in so far* as it enables a pattern to expand and propagate. In the end, however, it is the pattern that increases in representation, not the individual, nor the gene, and there are situations in which an individual’s increased ability to survive and reproduce do not translate into that individual’s trait profile increasing in representation, as was shown in section 1.1.4.

6.4 Further insights

6.4.1 Evolutionary forces

Evolutionary forces, as defined in chapter 5, only provide *ex post facto* insight in or explanation of a given evolutionary trajectory. Even though they are well defined mathematically, they can only be identified after the fact. In other words, only after a given evolutionary trajectory has concluded, is one able to assess concrete evolutionary forces which produced said evolutionary trajectory. Because of this, analyzing the evolutionary forces which act or have acted on a population have no inherent predictive value. One might conjecture that, if a certain evolutionary force is the ‘main driver’ of evolutionary change over some period of time in the past, that, it will also be the main driver of evolutionary change for some time in the future, but such conjectures are extrapolations of trends rather than the force based predictions one employs while using Newtonian mechanics.

Evolutionary forces are system-level as opposed to ensemble level properties.⁹

⁸Another interesting conclusion, which for the sake of brevity I have not worked out, is that the evolution of eusociality has, in principle, nothing to do with inclusive fitness. Whether or not a queen ant is genetically related to her sterile worker ants is of no real importance. As long as the pattern as a whole propagates and expands, it simply does not matter how related its sub-patterns are. Some humans, for example, consider their life less valuable than the preservation of their intellectual endeavors even though there is no genetic relatedness between them.

⁹Not sure if property is the appropriate term in this context, but I am unable to conceive of a more adequate term as of writing.

Evolutionary forces are, therefore, much like system-level natural selection, which can also only be identified after an evolutionary trajectory has concluded.¹⁰ For contrast, ensemble-level natural selection has genuine predictive value (if one is able to assess it accurately), since it gives us reason to believe certain evolutionary outcomes are *more likely* than others. Evolutionary forces, therefore, should be understood as a tool that makes a given evolutionary trajectory *intelligible*, not as a tool that allows one to *predict* the future state of a population's trait distribution.

6.4.2 Trait carriers

In the context of debates about biological individuality and the unit of selection, it is interesting to observe that, mathematically speaking, trait space does not distinguish individuals from groups. Fundamentally this property derives from the fact that, if one were to fine grain one's trait space enough, one would eventually re-obtain the configuration spaces discussed in chapter 4. In these configuration spaces, it simply does not matter how one 'draws the boundaries around aggregates of matter', for these boundaries are fictional in nature.

Trait space also reflects the fact that individuation is arbitrary and artificial in nature, because a collection of N trait carriers in n dimensions can also be represented as a collection of M trait carriers in m dimensions. Taking the extremes, the mathematical representation of a collection of 100 individuals with 5 distinct traits can either be done through 100 trait carriers in 5 dimensions or as 1 trait carrier in 500 dimensions. In other words, the traits of an organism are as much traits of the population of cells that constitute the organism, as well as of the population the organism is a part of. Consequently there is no unique or correct level at which to evaluate the 'benefit' or 'function' of a trait, since a trait of a unit at the l -th level of biological organization is, in principle, also a trait of the units at the $(l - 1)$ -th level of biological organization and at the $(l + 1)$ -th level of biological organization. It is the timescales and not the spatial scales which make all the differences. But, given that larger spatial scales are often accompanied by larger timescales, this distinction seems to have gone largely unnoticed.

6.4.3 Overlapping identities

One advantage of the Configurationalist approach, like with comparing fitness values between species of different sizes, is that one can assign fitness to patterns with overlapping individuations, because the total volume occupied by a collection of atoms in the atomic-grid is independent of how they are individuated. In figure 6.1, for example, the pattern realized by three red blocks in an L-shape can be individuated a total of twelve times in perception. Fortunately, since the total volume occupied by the pattern 'three red blocks in an L-shape' is invariant under individuation, one does not have to worry about whether one has 'correctly' individuated the patterns. The advantage is that in the context of, for example, holobionts, in which the notion of an individual is rather fluid,

¹⁰Talking about the beginning and end of an evolutionary trajectory is a metaphorical way to describe an evolutionary trajectory over a given time period. The population might very well keep on evolving 'after the end of the evolutionary trajectory'.

one does not have to worry about ‘picking the right individuation’ in order to assign fitness values.

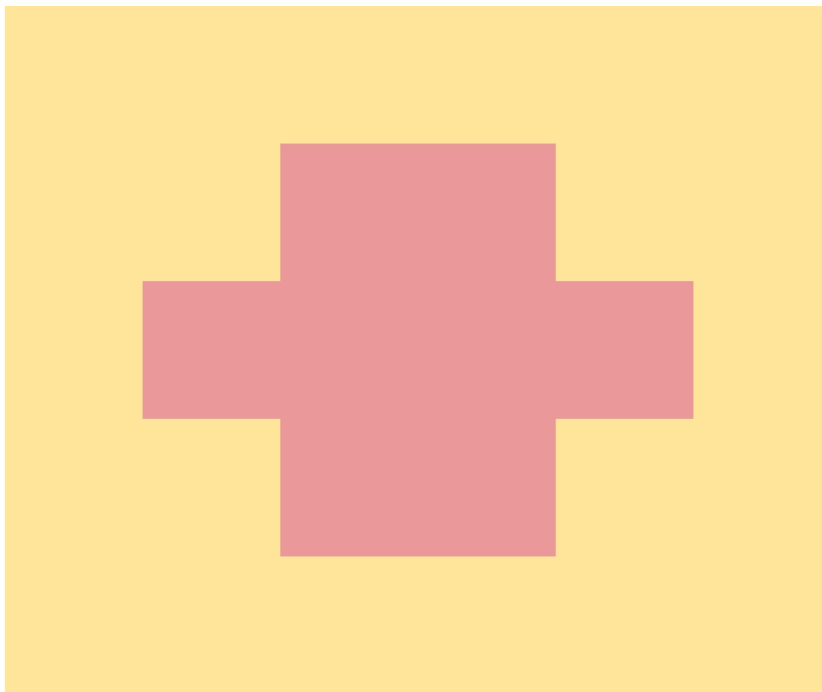


Figure 6.1: There is a total of twelve ways in which one can find three red blocks in an L-shape. The total volume occupied by all possible instantiations of the pattern under these different and overlapping individuations is the same however.

6.5 Chapter summary

Based on the distinction between natural selection, drift and fitness at the system-level and ensemble-level it was argued that system-level selection should be understood in terms of *outcome* and ensemble-level selection in terms of *process*. It was also argued that neither system-level nor ensemble-level selection were *causes* of evolution and that, in particular, system-level selection was a *form* of evolution.

Furthermore, it was also argued that there is no unit of selection, not in the sense of a fundamental unit on which all intergenerationally transmitted fitness increasing traits accumulate, nor in the sense of a unit for whose ultimate benefit traits evolve or on which natural selection ‘acts’.

Finally it was argued that from the perspective of evolutionary theory, fitness should be understood as a *growth rate* associated with a pattern in terms of the rate at which it increases its volumetric occupation and not a *disposition* associated with an individual in terms of its ability to survive and reproduce. When studying the distribution of traits within a population this meant that fitness could be understood in terms of the rate at which a trait or trait profile increases in representation within said population.

Chapter 7

Conclusion

“I know that you can do all things; no purpose of yours can be thwarted. You asked, ‘Who is this that obscures my plans without knowledge?’ Surely I spoke of things I did not understand, things too wonderful for me to know. You said, ‘Listen now, and I will speak; I will question you, and you shall answer me.’ My ears had heard of you but now my eyes have seen you. Therefore I despise myself and repent in dust and ashes.”

– Job, Job 42:2-6

7.1 The problem

This thesis started with the hypothetical example of a planetary fungus in order to argue that, in principle, evolution without reproduction was possible and that, furthermore, the traditional Darwinian understanding of evolution by natural selection in terms of the differential survival and reproduction of individuals in a population based on their trait profile was unable to properly account for the evolution of such a fungus. This hypothetical example, supported by the very real examples of tree groves and sterile worker castes, as well as the phenomenon of niche construction, extra-genetic inheritance and horizontal DNA transfer, was then used to argue that the Darwinian understanding of the struggle for existence in terms of individuals competing for survival and reproduction was too restrictive and failed to properly account for the evolution of non-reproducing biological individuals.

It was then argued that Darwinism suffered from multiple other problems too. It was argued that Darwinian evolutionary explanations, at times, felt either *ad hoc*, *confused* or *lazy* and that these problems found their root in the idea that organisms *adapt* to their environment and that their traits serve important evolutionary *functions* which *benefit* to organism in its struggle to survive and reproduce.

The problem with Darwinian evolutionary explanations was that instead of using the concepts of adaptation and function as heuristic tools to *make sense*

of why a given trait evolved, it was said that a trait evolved *because* it performed a given function. In other words, the cogency of such Darwinian evolutionary explanations *hinged* on the ability to correctly identify the function of a trait, as this would determine its evolutionary future.

It was also argued that, more broadly, the restrictiveness of the Darwinian understanding of the struggle for existence combined with its dependence on function in order to give ‘scientific’ explanations gave rise to *arbitrary* and *artificial* distinctions between, for example, individuals and groups in the case of multi-level selection; individuals and their environment in the case of niche construction and, hence, between biotic and abiotic forms of evolution.

Finally, it was also argued that, even if Darwinism was without internal problems, it would still face the external problem of whether or not it would be compatible with a naturalistic view of the universe based on classical Newtonian physics: If everything is determined by the initial conditions of the universe combined with the laws of physics, it is unclear how (1) Paley’s design problem was solved and (2) what explanatory role there was left for natural selection. How can organisms adapt to their environment, if the evolution of both the organism and its environment were set in stone by the arbitrary initial conditions of the universe and its laws of physics, as opposed to ‘guided’ by the ‘force’ of natural selection?

7.2 The solution

In order to address these concerns a new interpretative framework was proposed named Configurationalism, which *rejected* the idea that organisms adapt to their environment and that their traits perform functions and *generalized* the struggle for existence from being about individuals competing for survival and reproduction to patterns competing for volumetric occupation. Natural selection, instead of being about the differential survival and reproduction of individuals (e.g. DNA molecules and organisms) was re-conceived as the differential spatial expansion and temporal propagation of patterns (e.g. trait profiles and species). Fitness, instead of being about an individual’s ability to survive and reproduce, was about the rate at which a pattern increased in volumetric occupation. In the context of evolutionary theory this was shown to translated to the rate at which a trait or trait profile increased in representation.

This thesis then explored and developed a theoretical framework to accommodate for these insights which, ultimately, resulted in the development of a Configurational evolutionary theory in chapter 5, in which the evolution of a population, or any trait carrier really, could be described by means of an evolutionary trajectory through trait space. These trait spaces found their grounding, however, in the weighted configuration spaces analyzed in chapter 4 in which both the effects of perceptual and dynamical bias on the spatial expansion and temporal propagation of patterns was discussed.

The core question Configurationalism, like Darwinism, tried to answer was ‘Why do I see more A than B’. Configurationalism explored this question in terms of both *perceptual* as well as *dynamical* biases and analyzed the propagation of patterns in perception in terms of the micro-configurations of matter which

realized these patterns in perception.

To increase tractability, as well as conceptual clarity, the configuration spaces were coarse grained down to trait spaces in order to describe the evolution of a population of trait carriers which, in the context of biological evolution, was a much more intuitive line of thinking. Using this trait space representation of biological evolution it was shown that selection, fitness and drift have both system-level as well as ensemble-level interpretations. Whereas system-level selection, fitness and drift described genuine physical properties and processes, ensemble-level selection, fitness and drift described the more abstract property of how representative a given evolutionary trajectory was with respect to all the other possible evolutionary trajectories of an evolutionary system given our initial knowledge about its macro-state.

7.3 The implications

Even though there are many philosophical implications that follow from a Configurationalist understanding of biological evolution, three were discussed in particular: The nature of selection, the unit of selection and the nature of fitness. With respect to the nature of selection it was argued that there were two distinct types of natural selection: system-level selection, defined in terms of the shape of an evolutionary trajectory, and ensemble-level selection, defined in terms of the representativeness of an evolutionary trajectory. This distinction between system-level and ensemble-level selection elucidated the problem of whether natural selection should be understood as an outcome or as a process. System-level selection was about whether the outcome was right (i.e. there was differential spatial expansion and temporal propagation), while ensemble-level selection was about whether the process (i.e. the reasons) were right (i.e. representative). It was also shown that neither system-level selection, nor ensemble-level selection were *causes* of evolution. It was shown instead that system-level selection was a *form* of evolution while ensemble-level selection was nothing more than an *epistemic tool* similar to the concept of entropy in physics.

With respect to the unit of selection it was argued that, given the fact natural selection was neither a cause nor an evolutionary force, it made no sense to define the unit of selection in terms of the unit that selection *acts on*. It was also argued that, given the fact that organisms do not adapt to their environment, it made no sense to define the unit of selection in terms of for whose (ultimate) *benefit* an adaptation evolved. Consequently, from the Configurationalist perspective, the unit of selection debate appeared deeply misguided. Instead it was argued that patterns propagate as a whole and that the evolution of a pattern can not be reduced to the evolution of one of its parts (i.e. sub-patterns).

In other words, the evolution of a species at the organismal level cannot be reduce to the evolution of its DNA at the genetic level. The inter-generational transmission of environmental structures (e.g constructed niches) and learned behaviors (e.g. cultural traits) is just as important as the inter-generational transmission of genetic material (e.g. DNA molecules). Instead of treating a beaver damn build by a previous generation as the static background for the beavers in the current generation, one can take a more holistic view and study

the evolution of ‘beavers and their dams’ as a single pattern. If one drops the artificial distinction between organisms and their environments, one will see that environments are not static selectors, but dynamic interactors co-evolving with a species as a whole.¹

With respect to the nature of fitness it was argued that fitness should be understood in terms of the rate of volumetric increase or representation of a pattern rather than the ability of an individual to survive and reproduce. In particular this meant that, within the context of biological evolution, fitness should be understood in terms of trait fitness as opposed to individual or ecological fitness.

7.4 The advantages

The advantage of Configurationalism over Darwinism, it was argued, was its ability to make sense of all physical evolution, including biological evolution, without running into either conceptual confusion, like was the case with individual vs group selection, or without unnecessarily excluding the evolution of certain organisms because they are not ‘actively reproducing’. The evolution of a spatially expanding organisms, like a giant fungus, or of sterile worker and soldier castes in eusocial insects colonies was easier to understand from the perspective of Configurationalism, since Darwinism could not even assign fitness values to these individuals, at least not in terms of reproductive output, without having to fragment its understanding of fitness into multiple incompatible fitness measures.

Another advantage to the way in which Configurationalism defined fitness, was that it allowed for cross-species fitness comparisons. Given that fitness could be assigned to any pattern, and that the rate of volumetric increase normalized fitness with respect to the product of size and reproductive rate, it allowed one to compare the fitness of ‘ants’ with that of ‘elephants’. Whereas a Darwinian comparison, in terms their reproductive outcome, proved meaningless due to the differences in size and rate of reproduction, Configurationalism could easily and meaningfully compare the differences in their rates of volumetric increase.

Moreover, given that fitness expressed the rate of volumetric increase over a particular time-frame, it became obvious that fitness was a time dependent variable. When comparing fitness values, therefore, one would have to specify the timescale over which that fitness value was measured. Instead of claiming that individual selection favors selfishness, since selfishness increases the fitness of the individual, and that group selection favors altruism, since altruistic individuals increase the fitness of the group, one would have to normalize for the differences in timescales over which individuals and groups propagate through time. Instead of comparing *between* and *within* group selection, one would, instead, compare *short-term* and *long-term* selection and find that, on the short term, there is selection for selfishness both at the individual and at the group level, but that in the long term, there is selection for altruism both at the individual and at the group level. This situation, it was argued, was similar to

¹To use Darwinian vocabulary: species adapt to environments, but environments also adapt to species.

a decaying particle with a 0.1% chance to decay per unit time, which, over short-time scales (less than 10 units of time) is highly unlikely to decay, but over long-timescales highly likely to decay (more than 1000 units of time), even though the decay process, like the process of natural selection, is exactly the same in both scenario's.

Furthermore, whereas Darwinian evolutionary theory ran into conceptual problems when faced with 'overlapping identities', for example, because what appears to be an individual from one perspective, appears to be a group from another, Configurationalism did not: it did not required one to ontologically individuated and distinguish the configurations of matter that realized a pattern and its sub-patterns. Similarly, the distinction between organism and environment, as well as the distinction between biotic and abiotic faded in light of the Configurationalistic approach. Even if a pattern overlapped multiple times with itself (like a Necker cube), this still would not constitute a problem, since the total volume occupied by the configurations of matter which realized those pattern(s) would be invariant under the different methods of individuation.

7.5 Thesis summary: Configurationalism as a critical love letter to Darwinism

In summary, Darwinian evolutionary theory is a good theory for making sense of the biological evolution of sexually reproducing organisms. In recent times, however, scientists have extend the explanatory scope of Darwinism to include everything from molecular evolution to cultural evolution. Even though the attempt is noble in nature, it has resulted in a fragmentation of Darwinian evolutionary theory's conceptual unit. In its current state it cannot account for the full range of observed evolutionary phenomena from first principle, as exemplified by the recent criticism of Neo-Darwinism from both proponents of *The Third Way of Evolution* and *The Extended Evolutionary Synthesis*.

Configurationalism, I believe, solves many, if not all, of these problems by noting that the idea that an organism's traits perform a function which helps the organism in its struggle for survival and reproduction, for all its heuristic value in *making sense of* a given evolutionary phenomenon, fundamentally cannot explain the reason it evolved. Besides rejecting the scientific legitimacy of this 'biological design thinking', it also generalized the struggle for existence in order to accommodate the evolution of non-reproducing but evolving individuals. In doing so, it did not require different and incompatible trains of thought, but instead unified all forms of physical evolution, including biological evolution, under the same general principles and concepts.

Configurationalism, then, in the final analysis, provides the keys to understanding biological evolution in its most general and diverse forms. Free from the arbitrary and artificial distinctions between individuals, groups and their environments, free from the restrictive understanding of natural selection in terms of the differential survival and reproduction of individuals and, perhaps, more importantly, able to recognize the wholeness of the organisms while still being fully reducible to and compatible with classical Newtonian physics.

In short, Configurational evolutionary theory is the next stage in the evolution of evolutionary theory. A liberation from the confused clutches of biological design and a generalization of one of the most powerful ideas ever conceived by man, namely, the struggle for existence.

Appendix A

Configurations and States

In chapter 4 the basic ideas underlying a Configurationalistic conception of physical reality were discussed and in chapter 5 insights gained from this conception of physical reality were applied to the domain of biological evolution. This appendix further elaborates on the conceptual ontology of Configurationalism. In particular the relation between *configurations* and *states* is discussed in a more technical manner as well as the relation between *patterns* and *configurations*.

A.1 Defining configurations

The evolution of the universe is conceived of as a *sequence* of configurations of matter, or configurations in short. In principle there need not be any relation between the configuration in this sequence. In other words, a configuration at time t need not be related to any of the configurations at times before or after t . In general, however, we operate under the assumption that the configurations in this sequence *are* related.

For simplicity sake, I shall explain the relation between configurations and states using a toy model. The toy model consists of 3 spatial dimensions and 1 temporal dimension. Time ticks in discrete steps of Δt and runs from $t = 0$ to $t = T$. Space is divided into ‘cubes’ of size $\Delta x \Delta y \Delta z$ and runs from $x = 0$, $y = 0$ and $z = 0$ to $x = X$, $y = Y$ and $z = Z$.¹ Each cube has a ‘property when probed’ but, for all intents and purposes, these can be thought of as (abstract) atoms of differing types occupying the center of each cube.

It should be noted that, in principle each cube can be conceived of as containing a large data matrix which, when probed, returns some value. Based on those values, one can then associate some conceptual entity, like an ‘atom’, with certain regularities observed in the return of those values. Even though the concept of a property when probed is more general than an ‘atom confined to some small

¹The decision to start at $t = x = y = z = 0$ is of no significance, one might as well have started at some other value like, for example, $t = -T$, $x = -X$, $y = -Y$ and $z = -Z$. The only thing to be aware of is that in the limit of $T \rightarrow \infty$ one might introduce an ‘actualized infinity’ (i.e. an infinity that has been actualized by subsequent addition) into the toy model depending on one’s conception of time.

area in space', it does not provide much extra insight into the inner workings of configurationalism. Whether one wants to know why one sees more A than B, smells more A than B, hears more A than B, etc., simply does not matter. The only thing that matters is that certain elements in sensory experience are more abundant than others and that Configurationalism provides a way to make sense of this discrepancy in terms of the differential spatial expansion and temporal propagation of the configurations of matter which give rise to those individuated elements in perception (i.e. patterns). It is also for this reason that, before one can analyze the dynamical biases giving rise to the differential spatial expansion and temporal propagation of patterns, that one must 'filter out' the perceptual biases.

For finite values of Δt , Δx , Δy , Δz , T , X , Y and Z the total number of possible sequences of configurations is also finite. Each possible configuration can be represented as a point in a configuration space and any sequence of configurations can be represented as a trajectory through this configuration space in terms of a sequence of ordered points.²

A.2 From configuration space to trait space

In figure A.1 the process of coarse grinding one's configuration space in order to obtain a trait space is shown. Given that a system's configuration space does not have to be structured, one must first structure one's configuration space by grouping together the relevant micro-configurations based on the macro-configurations they realize. In this case the micro-configurations are grouped together base on whether or not they realize a population in which the majority has a green fur or a red fur. After the micro-configurations are grouped together one then coarse grinds the configuration space by simply reducing the configuration space to a trait space with the traits majority green and majority red.

The reason this process is important, is because it allows one to establish trait spaces on different levels of physical organization, thereby justifying the use of the 'Darwinian vocabulary' of fitness and selection, as introduced in chapter 5, at different levels of physical organization. Whether one wants to analyze the evolution of cars or the evolution of ants does not matter: in both cases Configurational evolutionary theory is applicable.

A.3 Defining states

Given some initial configuration at $t = 0$, without dynamical bias (i.e. no relatedness between configurations at different times at all), all possible sequences of future configurations are equally likely. Each such a possible sequence of future configurations is a potential state the system (i.e. the toy universe) could be in.

²It should be noted that a configuration space does not, by virtue of being a configuration space, have an internal structure in terms of where each configuration in configuration space is located with respect to the other configurations in configuration space. One *can* impose such a structure on a system's configuration space based on, for example, the macroscopic outcomes one cares about, but such a structure *does not* reflect some inherent property of a system's configuration space.

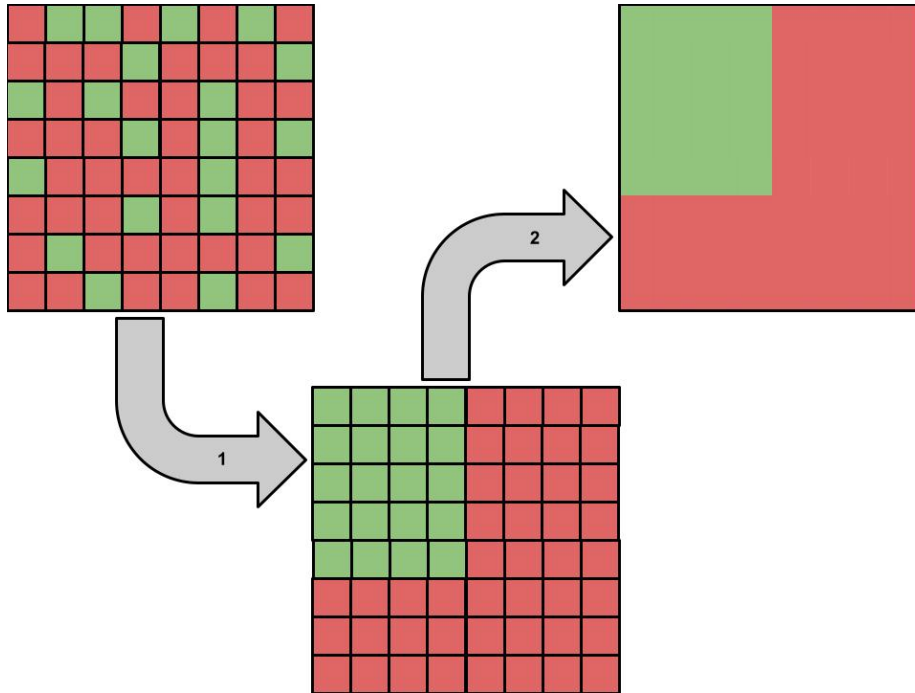


Figure A.1: In step 1 one structures ones configuration space in terms of grouping the micro-configurations that realize the same macroscopic outcome at the level of a population’s trait distribution together. In step 2 one moves from the individual micro-configurations in ‘configuration space’ to two macro-configurations or ‘trait-states’ in ‘trait space’.

The actual evolution of the system, however, will consists of only one sequence of configurations. The actual sequence of configurations, starting at $t = 0$, is called the *true* state of the system at $t = 0$.

If one restricts the possible future configurations of a system (i.e. the system’s states) one is introducing a dynamical bias. If one, for example, imposes object permanence, one will restrict one’s analysis of the possible states of one’s system only to those states which are comprised of a sequence of configurations in which the total number of atoms of each type is conserved, in other words, the total number of atoms of each type at time $t = \tau$ must be equal to the total number of atoms of each type at $t = \tau + \Delta t$ for all $\tau \geq 0$. One might also impose continuity in terms of atoms only being allowed to ‘swap place’ with one of their neighbors and swap no more than one time per time-step Δt .

All of physics is, in essence, an attempt to narrow down the possible states a system could be in by restricting its available states using dynamical biases, thereby reducing the number of possible future sequences of configurations one has to account for with respect to one’s behavioral output. Obviously this is done in a much more complex and sophisticated way than mere object permanence, but the idea is the same. Even though classical physics, for example, expresses its states in terms of particles with masses, charges, accelerations, velocities, locations, etc., including error margins, these classical states are, from the Con-

figurationalistic perspective, nothing but an attempt to reduce the number of states available to a system (i.e. its potential futures).

Two special cases are of interested when discussing dynamical bias: *no* dynamical bias and *absolute* dynamical bias. If there is no dynamical bias then given some configuration at time $t = \tau$ there is absolutely no restriction on the configurations possible at $t = \tau + \Delta t$. If there is absolute dynamical bias then given some configuration at time $t = \tau$ there is only one configuration possible at $t = \tau + \Delta t$. In other words, the configuration at $t = \tau$ fully determines the configuration at $t = \tau + \Delta t$.

In the case of no dynamical bias there is no need to analyze a system's state space in order to determine the weights of the system's micro-configuration, because the number of micro-states associated with each micro-configuration is equal. Moreover, the distribution of configurations in configuration space is equal to the distribution of states in state space in terms of how likely it is at any time t for some micro-configuration c to be realized.

In the case of absolute dynamical bias there is also no need to analyze a system's state space, because each configuration in configuration space is associated with only one state in state space and, hence, the number of micro-states associated with each micro-configuration is equal. Moreover, knowledge of a system's configuration fully determines its state and, consequently, reduces one's configuration space to a state space in the sense that each point in configuration space fully specifies the future evolution of one's system.

A.4 Visual recap

In order to properly understand the relation between a configuration space and a state space consider figure A.2. In the top left figure three sequences of configurations starting with the grey configuration are shown for three time steps: a red sequence, a green sequence and a blue sequence. These sequences can be represented as states in the grey configuration's state space. Each configuration in configuration space has its own associated state space, that is, a set of sequences of configurations whose initial configuration starts with the configuration the state space is associated with in configuration space.

Suppose that the red, green and blue states are each representative of a larger class of states. This is shown in the middle figure in terms of the red, green and blue regions. All the states in these regions are in some way similar to each other. If one imposes a dynamical bias on a system, one is effectively making certain states unavailable to the system. This is represented in the top left figure by the greyed out area which used to be the green area. In this scenario the dynamical bias is one that prohibits the system from being in states associated with the green states. In other words, this dynamical bias prevents the system from going through sequences of configurations which reside in the green region of the grey configuration's state space.

Obviously this a very simplified and highly abstracted representation of configuration and state spaces, but the general concepts and relationships discussed in here apply to all configuration spaces and state spaces, even those which are

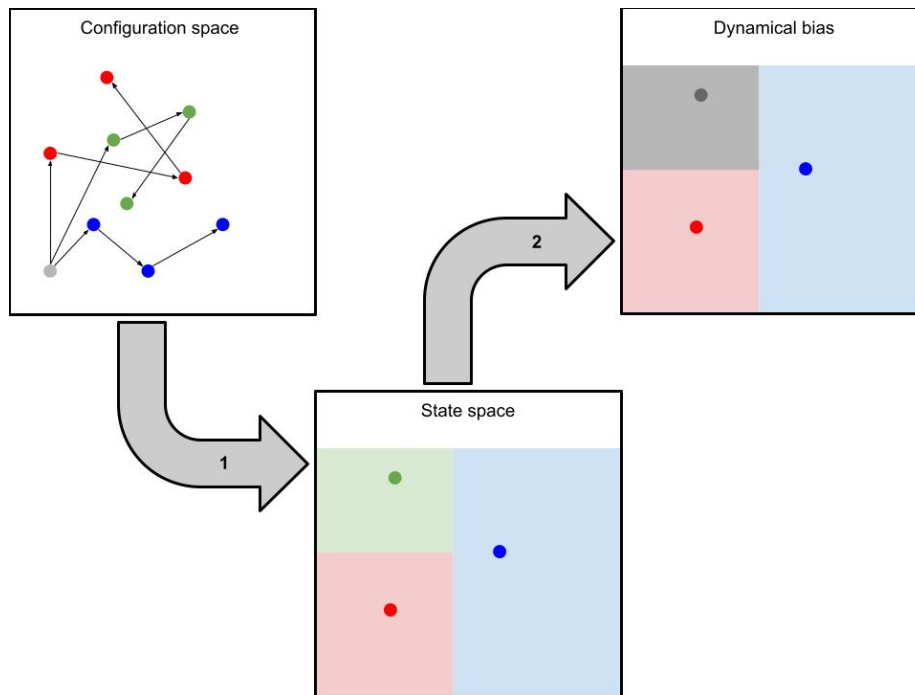


Figure A.2: A visual recap of the relation between configuration space, state space and dynamical bias. Each configuration in configuration is associated with its own state space. In this case the state space of the grey configuration is shown. The grey configuration has three macro-states in state space, green, red and blue. Each represents a certain type of trajectory through configuration space. If one imposes a dynamical bias then one restricts the available states associated with a configuration in configuration space. In this example the green states are no longer available due to dynamical bias and they are ‘greyed out’.

more concrete and, therefore, more complicated.

A.5 Defining patterns

Patterns are configurations of matter which are individuated in perception. A pattern can, therefore, be *associated with* but not *reduced to* a set of configurations which, if perceived by an observer, realize an individuated entity in the perception of said observer. When trying to answer the question why one ‘sees more A than B’ one must account for two things. First, one must account for the fact that the sequence of configuration’s one observes might be ‘biased’ in the sense that configurations of a certain type are more abundant than others. In other words, one must account for dynamical bias. Second, one must account for the fact that the patterns one is interested in, namely A and B, might not be realized by the same number of configurations (assuming they are of equal ‘size’). Pattern A might, for example, be much easier to realize than pattern B in perception. In other words, one must also account for perceptual bias.

In practice it will be very difficult to determine the degree to which dynamical

and perceptual bias contribute to one seeing more A than B, but, at the very least, it is a useful conceptual distinction which helps make sense of the fact that, even if nature were absolutely unbiased in terms of which ‘configuration she picked next’ one might still observe more A than B, because one is simply more ‘sensitive’ to observing A than to observing B. In other words, it is not nature having a bias for A, it is you, as an observer, having a bias for A.

A.6 Dynamical and perceptual bias

The relation between perceptual and dynamical bias is best explained in terms of perceptual bias being the bias that ‘makes one see more A than B’ in a particular configuration and dynamical bias being the bias that ‘makes one see more A than B’ in a particular sequence of configurations. Even though perceptual bias dominates for each configuration in said sequence, the dynamical bias can dominate in the fact that a sequence of configurations might be biased in terms of the configurations it contains. In other words, one can conceive of perceptual bias as a bias related to the *instantaneous* perception of patterns while dynamical bias can be conceived of as a bias related to the *change* in the perception of patterns.

Using the example of the decay mechanic discussed in section 4.3.1 this means that if one were only provided with the fact that the system as a whole can be in one out of the sixteen configurations discussed, perceptual bias would dominate. The fact one would more often than not see orange would be a product of one’s perceptual bias in terms of one’s increases ‘sensitivity’ for orange. The fact that after some time one would always see yellow would be a product of the system’s dynamical bias in terms of the fact that the system’s states are such that they always end up realizing yellow for $t \geq 4\Delta t$.

A.7 Micro- and macro-states vs approximate- and true-states

There is an important distinction to be made between *micro-* and *macro-states* on the one hand and *approximate-* and *true-states* on the other hand. In principle, there is only *one* true-state of the entire universe (i.e. one true sequence of configurations which accurately describes physical reality). An approximate-state, on the other hand, is an attempt at narrowing down a system’s set of available states by specifying a macro-state (i.e. a set of micro-states) which contains the true-state as one of its *fundamental* micro-states.

The difference between a micro-state and a *fundamental* micro-state is that a macro-state at level l can have micro-states at level $l - 1$ even though the fundamental micro-states (one of which is the true-state) exists at level $l - \lambda$ $|\lambda| > 1$. To illustrate this difference consider a system which is described by a state S_{f_1, f_2, f_3} with three degrees of freedom f_1 , f_2 and f_3 where f_1 can be either A, B or C, f_2 can be either 1, 2 or 3 and f_3 can be either a, b or c.

If the system’s true-state is S_{A3a} then an approximate-state might be that the system is in the state S_{A3} . This leaves it unclear whether the system is in the

S_{A3a} , S_{A3b} or S_{A3c} state, but clear that it is not in any of the S_B , S_C , S_1 and S_2 states. Knowing that the system is in the S_{A3} state restricts the system's available states in state space to those states for which $f_1 = A$ and $f_2 = 3$.

When it comes to the concept of micro- and macro-states, it only makes sense to talk about a state at some level l being a micro- or macro-state if one also specifies some other state at some other level l' as being a macro- or micro-state respectively. Using the previous example, the S_{A3} state is a macro-state *with respect to* the S_{A3a} , S_{A3b} and S_{A3c} states, but a micro-state with respect to the S_A state.

A true-state is always a fundamental micro-state with respect to any approximate-state, and can never be a macro-state, as there is no level of description more detailed than that of the true-state. Similarly, an approximate-state is always a macro-state with respect to a system's fundamental micro-states or true-state. An approximate-state, if accurate, is a set of (fundamental) micro-states, one of which is or contains the true-state. The reason I use the word *contains*, is because if the micro-states of the approximate-state are macro-states with respect to the fundamental micro-states, the true-state would be 'contained' in one of the sets of the micro-states associated with the approximate-state. It should be noted that for any state to qualify as an approximate-state it must contain at least two fundamental micro-states.

In the context of Configurational evolutionary theory, this is important, because if one models the evolutionary dynamics of an evolutionary system, one might specify one's micro-states (in trait space) in terms of individual trait profiles (e.g. a full information representation) while one might specify one's macro-states in terms of the statistical averages of these trait profiles at the population level (e.g. a reduced information representation). Just because one has defined their micro-state in trait space in terms of individual trait profiles, however, does not mean that one's micro-states are fundamental (i.e. at the level of the true-state) in the trait space's underlying configuration space.

A.8 Configurations and weights

Given some initial macro-configuration of a system and the dynamical biases that govern its evolution, one can determine the likeliness a given configuration manifests after some time τ by assign weights to each micro-configuration. The value of these weights is determined by the number of micro-states which, after some time τ realize said configuration.

Given some macro-configuration C_a which is realized by micro-configurations c_m^a in which $1 < m < m'$, each of which can be in micro-states s_n^m for each m in which $1 < n < n'(m)$, the chance that, after some time τ one finds the system in some other macro-configuration C_b is given by the proportion of micro-states s_n^m that, after some time τ realize a micro-configuration c_m^b which realizes the macro-configuration C_b .

If every micro-state is equally likely, then one can introduces weights $w(t)$ for micro-configurations and $W(t)$ for macro-configurations which express the number of micro-states which, given some initial macro-state, evolve such that after

after some time t they realize the micro-configuration or macro-configuration in question.

Similarly, one can also introduce weights $\omega(t)$ for micro-states and $\Omega(t)$ for macro-states which express the number of atoms that realize the pattern of interest in the configuration realized by the state in question after some time t . These weights help correct for the fact that even if only a few states realize said pattern, that if they do realize, the pattern is realized very often and, hence, very abundant in perception. For convenience sake, however, one can ‘contract’ the $\omega(t)$ and $\Omega(t)$ weights into the $w(t)$ and $W(t)$ weights respectively.

One can then use these weights $w(t)$, and $W(t)$ to define an ease of realization in terms of the number of micro-states that realize a given micro- or macro-configuration after some time t , given some initial macro-state, by dividing the number of micro-states that realize the micro or macro-configuration of interest by the total number of micro-states that are associated with the initial macro-state.³

In general, however, micro-states (unless they are fundamental) cannot be assumed to be equally weighted without further argumentation. Given some macro-state S realized by two micro-states s_a and s_b it might be that, given that s_a and s_b are not micro-states at the level of the true-states, there are more fundamental micro-states that realize s_a than s_b . In other words, if s_{a1} , s_{a2} and s_{a3} are the micro-states of s_a at the level of the true-states and s_{b1} and s_{b2} the micro-states of s_b at the level of the true-states, it would be incorrect to conclude that, just because S has two micro-states s_a and s_b within one’s level of analysis that, therefore, the weight $w_a(t)$ of the configuration c_a at $t = 0$ is equal to $1/2$ as opposed to $3/5$.

A.9 Fate and luck

In the context of macro- and micro-states one can also make sense of the terms ‘fate’ and ‘luck’ in terms of the weights of the micro- and macro-configurations on which one’s trait supervenes. If a given macroscopic outcome A is overwhelmingly probably (i.e. many fundamental micro-states realize said macroscopic outcome after some time t), it makes sense to say it was ‘fated to happen’. One could say that, based on the dynamical biases known to us, nature *selects* for such outcomes. Similarly, if a given macroscopic outcome B is rather unlikely (i.e. only a few fundamental micro-states realize said macroscopic outcome after some time t), it makes sense to say that, if one were expecting outcome A but one observed outcome B that one got ‘unlucky’.

A.10 Continuous generalization of the toy model

One cause for concern is that, within the toy model presented in this appendix, the universe is conceived of in terms of small but finite tesseracts. But why suppose the universe is ‘discrete’ as opposed to ‘continuous’ in nature? Why

³Actually it is integrated over a time interval of interest (as opposed to instantaneous) as to provide some measure as to how easily a pattern realizes in a give system over a given time interval given some initial macro-state.

assume that if one goes ‘deep enough’ one will eventually find the ‘true-state’ of nature. If anything, does the appearance of chaos in deterministic physical systems not show that eventually two nearly identical initial micro-states can still produce significantly different macro-configurations after some long but finite time τ . In other words, no matter how well one specifies one’s micro-state, can we ever be certain that said micro-state is entirely accurate for the entire sequence of future configurations over all space and all time? In other words, can we ever be certain that our micro-state is the true-state?

The simple answer is that we can never be certain, not even in principle. But this has more to do with our epistemic limitations as human observers rather than ontological limitations of a configurationlistic approach and conception of physical reality. Even if we knew every law of physics, if those laws happen to be ‘sensitive’ to the exact initial conditions one feeds into them, one might still observe vastly different evolutions after enough time has passed. Consequently, unless one can also measure the variables needed to make predictions with ‘infinite exactness’, one can never be certain that one’s predictions will be accurate for all times over finite, but large timescales.

One can, however, ‘approximate’ a continuous universe by using the following limits in which $\Delta t \rightarrow dt$, $\Delta x \rightarrow dx$, $\Delta y \rightarrow dy$ and $\Delta z \rightarrow dz$ and $T \rightarrow \infty$, $X \rightarrow \infty$, $Y \rightarrow \infty$ and $Z \rightarrow \infty$. Then, instead of ‘summing over’ t , x , y and z using steps of finite size one ‘integrates over’ t , x , y and z using steps of infinitesimal size.

In principle, therefore, this Configurationalistic approach to the universe can be extended ‘all the way down’ if it turns out that the universe cannot be accurately described over all space and all time by ‘going down’ a finite number of levels. In other words if every state at every finitely deep level of organization always has more micro-states underneath it which, given enough time, will manifest in different macroscopic outcomes after some very long but finite time τ . Mathematically speaking one will have to redefine one’s weights from being in terms of the *number* of states to being in terms of, for example the *density* of states in a specific region of a structured state-space. Conceptually speaking, however, one is not doing anything drastically new.

This does not mean there is no true-state: there is only one actual evolution of the universe. Stating that the outcomes are ‘set in stone’ always applies. The sequence of configurations is ‘set in stone’ by the actual or true-state of the universe. It does mean, however, that one cannot *know* this true-state by conducting measurements with finite measurement accuracy, at best we try to devise micro-states which have enough ‘spatio-temporal resolution’ to accurately predict the configuration of the universe at future times with respect to the outcomes we care about.

A.11 From exact configurations to approximate states: Integrated states vs instantaneous states

Suppose we grant the fact that the universe is a sequence of configurations and that each configuration in configuration space is associated with a plethora of states in state space, how do we then determine those states in actual reality? Given that we can only observe sequences of configurations and have no accesses to these ‘instantaneous states’, what should we do?

The answer is to use time-integrated states as opposed to instantaneous states (hence the talk about the eyes as spatio-temporal integrators in section 4.2.3). Suppose we have the ability to analyze the universe at the level of $l - \lambda$ but only care about the outcomes at the level of l . Suppose that, effectively, this means that at the level of l we describe the universe in terms of Δ 's and at the level of $l - \lambda$ in terms of δ 's. Suppose, furthermore, that $\Delta = n\delta$. In other words, for each tesseract at level l there are n^4 tesseracts at the level of $l - \lambda$.

Even though one cannot access the states at the level of $l - \lambda$ one can access the configurations at $l - \lambda$ and use those to construct states at the level of l based on the differences between configurations at $l - \lambda$ contained in intervals of length $n\delta t$.

To illustrate this idea using classical mechanics. If one is provided a list of locations of size m describing the motion of an object O_a in the presence of another object O_b then, one can use that list of locations to compile a list of (approximate) velocities of size $m - 1$ and a list of (approximate) accelerations of size $m - 2$. The list of velocities and accelerations can then be used to determine if there is a systematic relation between, for example, the distance between O_a and O_b and, for example, the velocity and acceleration of O_a and O_b . One could, in other words, try to recover the dynamical bias often referred to as ‘gravity’.

In order to do so, however, one had to ‘coarse grain’ in the sense that the states used to describe any ‘real physical system’ are these types of integrated states derived from the careful study of the sequence of configurations a system goes through, as opposed to instantaneous states that, in theory, underlie those integrated states and are approximated by those integrated states.

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