Pretty Ugly

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Why we like some songs, faces, foods, plays, pictures, poems, *etc.*, and dislike others

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Cambridge Scholars Publishing

Pretty Ugly: Why We Like Some Songs, Faces, Foods, Plays, Pictures, Poems, Etc., and Dislike Others

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To the many people
who helped us
with this book

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The Field of Beauty

A Wayward Walkabout

The tribe in New Guinea lived so apart from the modern world that they still used stone axes. None of them had ever seen a photograph, and anthropologist Edmund Carpenter wanted to know how they would react to seeing one for the first time. He showed them Polaroid pictures of themselves and saw complete incomprehension:

> At first there was no understanding. The photographs were…far removed from any reality they knew. They had to be taught to 'read' them. I pointed to a nose in a picture, then touched the real nose, etc. Often one or more boys would intrude into the scene, peering intently from picture to subject, then shout, 'It's you!' Recognition came gradually.[1]

Looking at these men, it seems obvious that beauty is in the eye of the beholder—but more than beauty: reality too. Since they are not seeing reality in the photograph before them, the appearance of reality must also be in the eye of the beholder. The eye must learn how to see.

Or rather, the brain must learn how to see. The brain must learn how to see that a picture is an image of something, not merely splotches of colour.

The development of aesthetic preferences starts at this rudimentary level, and it does so not just for photographs and paintings but also for sculpture, dance, music, poetry, plays, food, drink, and all of our activities and endeavours. The aesthetic engine for all of these is the human brain. Although different parts of the brain end up doing different things, the underlying machinery is similar everywhere. The seemingly different parts of the brain are so alike and so intertwined that all of our aesthetic responses involve similar mechanisms, no matter what senses are involved. In this book we are going to lift the hood and see how the engine of beauty is constructed.

Conventional studies of aesthetics assume implicitly if not explicitly the cultural preferences of the author's time and place. For example, the 11th edition of the *Encyclopedia Britannica* is known as the "scholar's edition" for its depth and erudition. Its main entry on music is 14,000 words. This article dates from 1910, almost the peak of the British empire. It does not deign even to mention Africa.

Nobody could imagine such an omission today. Today, any overview of music purporting to be comprehensive would mention complex African polyrhythms. On the other hand, our current attitude may also be a distortion of the times, a distortion by a contemporary value we have developed in reaction to our colonial past, the desire to appreciate cultures that we have been destroying. According to Princeton Professor Kofi Agawu, a musicologist from Ghana, most observations of African music involve "the pious dignifying of all performances as if they were equally good, of all instruments as if they were tuned in an 'interesting' way rather than simply being out of tune, of all informants as if a number of them did not practice systematic deception, and of dirge singing as if the missed entries and resulting heterophony did not result from inattentiveness or drunkenness."[2]

This book is an attempt to understand aesthetics irrespective of culture. Of course we are children of our place and time like everybody else, so we are subject to similar biases, but we are hoping to sidestep them by basing the book not on aesthetic appreciations but on science. We are building it from basic work on the sensation, perception, and cognition of adults, and from studies of babies, who were young enough not to have been acculturated. Moreover, we are not creating a self-contained theory with its own system of explanation, we are founding an explanatory framework on physics, physiology, and evolution. Indeed, the next chapter is an introduction to some key concepts of physics and maths.

However, we did not write this book specifically for scientists. We also wrote it for artists, musicians, architects, cooks, writers, readers—anyone who enjoys any of the arts. We shall work with concepts, not equations, and show numerous examples.

Our argument will draw from many academic disciplines, each of which has a rich and idiosyncratic jargon. This presents a problem.

Although jargon can be a shortcut to understanding, it is a shortcut only to initiates, and few readers will understand the jargon of all the fields we need to walk through. Moreover, jargon is a shortcut that tends to lead the mind along conventional paths, paths that we shall need to avoid. For these reasons we shall use specialized jargon only in rare instances where ordinary English simply cannot serve, and then we shall explain it.

Few readers will have read in all of the fields we shall wander through, so our first approach to every field shall be introductory. However, introductory does not mean elementary. If we seem to start with Music 101—well, we shall not stay at that level for long.

Unfortunately, the scope of this book will force us to fly through subjects quickly. During these flights we shall make many assertions that contravene conventional wisdom, and some of these may sound bold and bald. If you find yourself rolling your eyes—if you find yourself wondering how the stupid authors could ignore something obvious that everybody knows—please visit the endnotes. These contain additional discussions and entrées to the academic literature.

Nature and Nurture

When we began to research this book, we envisioned ourselves describing the interaction of genetics and the environment. However, although nature and nurture are the most common explanatory mechanisms, we found that explanations based on either of them seem always to lead to a dead end, even when the notions are more sophisticated than "natural beauty." For example, inside the eye, three sets of conical, light-sensitive cells enable you to see different wavelengths of light as different colours. These cells respond to a limited range of wavelengths, so you cannot see any wavelengths outside that range. This is nature, this is how you are built. For this reason you will never hear a couturier wax lyrical about a lovely infrared or a soothing ultraviolet. However, to state this is merely to state that you cannot appreciate what you cannot see, which is neither helpful nor profound. Nor is nurture more helpful, because nurture by itself cannot explain why a suit of clothes might look lovely during the day but not at night.

Nature versus nurture is not a model that leads very far because physiology and learning are not separate and distinct, they are inextricable. Learning is not an abstract process, it is a physiological process, ultimately a chemical process, and chemical processes require both nature—the chemicals—and environmental factors like heat. For this reason, we tried to avoid the usual vocabulary of "hard wiring" and "environmental influences," and to seek more revealing explanations.

Ultimately we came to see the sense of beauty as an emergent phenomenon. An emergent phenomenon is something complex that arises from repeating something simple many times. An example is the office towers in a city. To prosper if not merely to survive, people need to exchange goods and services, so individuals have a fundamental need to trade. Proximity facilitates trading, so people decide to move near other people. A village forms. The concentration of people in a village attracts more people so the village becomes a town, then the town becomes a city. Eventually the city runs short of space. At that point people begin to build upwards and office towers emerge.

Physical beginnings—nature, if you will—always help to shape emergent phenomena. Amsterdam has soft soil at depths where New Amsterdam has bedrock, so taller buildings emerged in New Amsterdam (New York), but good harbourage saw dockyards emerge in both.[3]

Human bodies are another emergent phenomenon. Infinitesimally small chemical packets that we call cells combine with other cells, which combine to form the larger packets we call tissues, which combine to form organs, which combine to form a baby. At every stage in this process the packets do nothing more than react to the basic forces of physics and chemistry.

Genes do control the development of bodies but as geology controls the development of cities, not through active processes but through structural facilitation and constraint. This is apparent in the brain. The brain looks like a cauliflower and is formed in layers. Broadly speaking—very broadly—nerves to and from the body connect at the lowest levels, the middle levels run things, and the highest levels perceive and think. In none of these levels are the cells smarter than the cells forming a cauliflower. The brain's chemical structures are perfectly dumb, yet these dumb structures interact with one another in ways that permit intelligence to emerge.

Intelligence emerges primarily in the cortex, the outermost few millimetres that contain the highest levels of the brain. There as elsewhere in the brain, the environment of each neuron (nerve cell) consists of a chemical bath penetrated by erratic bursts of energy from one or another cell nearby. This energy reaches the neuron, passes along the neuron's surface in the form of a chemical chain reaction, then reaches the neuron's far end and crosses the chemical bath to nearby neurons. Its passage through the bath disturbs the bath's chemistry. It causes slight chemical changes that facilitate another passage of energy through the same route and inhibit the passage of energy through neighbouring routes. Those changes come to form neuronal pathways. From a vast number of these dumb pathways, intelligence emerges.

And our sense of beauty emerges from them as well.

Unfortunately, this emergence takes a confusing route—or rather, a confusing set of routes. To follow it we shall begin with some basic concepts of mathematics (without equations or numbers), then spiral upward repeatedly through vision and hearing. Eventually we shall reach art, architecture, dance, drama, literature, music, and sculpture. Halfway up the spiral we shall pause to sample tastes, smells, food, and drink.

SCIENCE *VS.* PHILOSOPHY

When we first thought about writing this book, we did not know what we could come up with. A framework that can hold all of aesthetics that is built upon basic physics—how to construct such a thing was not obvious. However, at physiological levels the brain is a machine, so we thought that we ought to be able to come up with something. In any case, we thought, the endeavour would be fun, because our research would take us to so many concerts and museums. That was 30 years ago.

A philosopher of aesthetics might have written a book like this faster. A philosopher could have forgone the museums and developed the argument from first principles using logic. But we are scientists, not philosophers. Scientists do not start from first principles, scientists try to make sense of what they see. In science, logic guides observations and explains observations, but observations come first and, although it sounds surprising, science does not follow the rules of formal, Aristotelian logic.[4]

To understand the reasoning of science, consider the basic paradigm of the scientific method:

1. Form an hypothesis. A new drug Memorine enhances memory.

2. Design an experiment to test the hypothesis. Give half a French class Memorine and half the class a placebo, and compare the two groups' vocabularies before and after the pill.

3. Run the experiment.

4. Examine the data and draw a conclusion. On average, students taking Memorine improved more than the others, so we infer that Memorine does enhance memory.

This sounds sensible and the conclusion may sound logical at first blush, yet that conclusion could not follow logically from any set of real data. We may see an improvement *on average* but among any group of students, some will learn more words than others for reasons having nothing to do with the drug. Among our group perhaps Alice heard a lot of French at her parent's cottage in Québec, and the Inuit Bunig never heard any French spoken until she went south to attend university, and Cora is a little dense, and Dorothy prefers dancing to studying, and Elena is already fluent in Spanish and Portuguese. We might be able to allow for some factors like these—perhaps we can exclude from our sample bilingual students—but we can never know about everything that might differentially affect students' learning. Thus, the most we can conclude is that Memorine *may sometimes* enhance memory.

This may sound like pedantry but it is not. Let us assert that all cats grow tails. If you have ever seen a Manx cat, you will contradict us. "No, it is false that *all* cats grow tails. *Not all* cats grow tails. *Some* cats grow tails but other cats do not." Now let's compare cats to Memorine. We hypothesize:

- All cats grow tails.
- Memorine enhances memory.

But according to Aristotelian logic, the results of our experiment show the *contrary* of our hypothesis:

- *Some* cats—*not* all cats—grow tails.
- Memorine *may sometimes* enhance memory.

Logically, no experiment can prove an hypothesis. All a scientist can do is assume that within an experiment, the influence of uncontrollable factors is the influence of random chance, and then calculate odds like a bookie. Instead of saying, "Memorine enhances memory," all we can do is report, "We saw an enhancement that would occur by chance less than *n*% of the time." That is the only logical conclusion we can draw.

Deductions like this are true insofar as they go but they do not go very far. To carry a man to the moon, or to analyze the elements in a gas, or to identify a pathogen, science requires sweeping inductions—generalizations from the particular to the general, like the generalization we accept as a law, that a body in motion tends to stay in motion. Yet according to the strictures of logic, all inductions are fallacies. No matter how many Italian meals you have eaten, you cannot conclude logically that all traditional Italian cooking uses garlic. Indeed, if you do conclude this, you will be wrong. Garlic was deemed the peasant's spice cupboard—sophisticates looked down on it—and Italian cuisine was developed not by peasants, who could afford little beyond grains and vegetables, but by folks with money in towns.[5]

The Art of Science

Science is not built from logical deduction, it is built from intuitive induction. Strengthening the inductions are associative reasoning—more about that shortly—and the mathematics of probability.

In principle these mathematics are simple. Let's illustrate them with our imaginary Memorine. A test of Memorine finds an amount of improvement that would occur by chance only five percent of the time. This may sound significant but it means the odds are five per cent that these results *did* occur by chance and that Memorine actually led to no improvement at all. To investigate further we test more drugs. We comb the pharmacopoeia and find 99 drugs in the same class as Memorine. We test each of them as we tested Memorine, and we repeat our test on Memorine as well. The result: five of these 100 drugs show results that would occur by chance five percent of the time. This result is exactly what one would expect by chance, so we see no evidence that this *class* of drugs is useful. However, one of these five drugs is Memorine, so now we have two studies each finding odds of five percent that Memorine can be effective. The odds that both studies found this by chance are lower. Next we test Memorine a third time and find similar results, so the odds become lower still. Now we feel justified to make an inductive leap, to conclude that, although most of the drugs seem useless, Memorine can be effective.

In principle that is how science works, but reality is dirty. Scientists do not enjoy repeating experiments, nor can we advance our careers by doing so. Scientists repeating an experiment will usually vary some circumstance, to extend what is known and to extend their lists of publications. Probably no one would retest Memorine with students learning languages but someone might test women in a nursing home on telephone numbers, and a neurophysiologist might give it to rats running mazes. Since each of these studies is different, we could not combine them mathematically. We would be adding apples and oranges. On the other hand, if they showed similar results, they would appear to be converging on a truth.

Converging evidence this is called. It is arguing by association rather than logic, so to a logician it carries no force, but it holds all of science together. For example, although no one can prove logically that all species evolved, yet (1) we have seen some species evolve in our lifetimes, (2) we can put together plausible evolutionary trees from physical evidence, (3) we can induce other species to evolve in the lab, and (4) no one has come up with an alternative more plausible than a *deus ex machina*. This evidence converges so strongly that scientists are forced to see the theory of evolution as more than "just a theory." Overwhelming converging evidence forces us to conclude that evolution is a mechanism that is fundamental to the development of life in all its forms.

In this book we paint a picture from converging evidence. A large picture from an immense body of evidence, evidence from several

SELECTING EVIDENCE

When a teacher demonstrates a classic experiment, the result is seldom exactly what the theory predicts it will be. The world is too messy for theoretical perfection to exist. Moreover, once we leave the basic textbooks, theories cease to be complete and coherent, and observations begin to be so messy that experimental results may look real yet not be. For example, consider Memorine again. By convention, scientists in most fields deem a result to be significant statistically if it has no more than a five percent probability of happening by chance. This means that if our results were entirely random, the most extreme five percent would still look significant. They could not *be* significant, for they were random, yet out of every 100 tests, five results would *look* significant.[6]

This will happen often because scientists hunt in the dark. Although we aim at noises, most noises at night come not from animals but from wind. In experimental psychology something like one-half of studies find no data that are strong enough to publish, despite biases to see significance wherever the psychologist looks.

Even when we hear a noise so loud that we know something is present, still we cannot draw a clear bead on our target. No scientific study can control and measure everything well enough always to reveal a phenomenon that actually exists. For a typical study in experimental psychology the odds are only about one in two or three of finding (a) an apparent statistical effect that (b) is not random. In neuroscience the odds are usually lower. Thus, if a study fails to find an outcome that other studies predict, there is an excellent chance that the study is at fault.[7]

An essential part of science is discriminating meaningful results from meaningless results. Alas, journals rarely publish failures to replicate experiments—word of mouth is often the only way to learn of failures to replicate—and once a scientist enlarges his scope beyond the minutiae of his own research, where any paper is expected to discuss every other paper, he will be open to the charge of selecting his evidence to fit his conclusion.

But selecting evidence is not a scientific sin, it is a scientific necessity. Scientists must discriminate among studies based on a sophisticated understanding of statistics and methodology plus sufficient knowledge of a field to know where evidence converges. In science, sin does not lie in discrimination and selection, sin lies in applying prejudice to discrimination and selection.

sciences plus anthropology and the history of the major arts. Like all evidence of every kind, our body of evidence is not completely consistent, but we do not take inconsistencies lightly and we discuss the more important ones in endnotes. The body of evidence that we deem solid coheres along many dimensions.

Finally, we would like to end this introduction with a pedantic note on attributions. For brevity we sometimes use “we” to refer to only one of us, or—in the text but not in the endnotes—to refer to any set of colleagues and/or students with whom Daphne has collaborated. Also, in the text we ascribe studies to the lead author only. Almost every scientific study is actually a collaboration, so if you see only one name, please read an implicit *et al.* and check the endnotes if you want to know who the others are.

2

Background

Some Arcane Corners of Science

Nico Machus is a modern son of Aristotle, a Professor of Philosophy, a bearded intellect who treads all walks of learning but particularly enjoys the path to the faculty club's bar, where he takes lunch and then a short, black espresso.[1]

A short, black espresso is remarkably bitter yet Machus not only drinks one, he savours it. He deems it an aesthetic pleasure. But examined objectively, this pleasure is bizarre. Nobody is born able to enjoy or even to swallow anything so bitter. If you put a drop of something so bitter as espresso onto a newborn baby's tongue, he will grimace and spit it out. Bitterness portends poison. Avoiding it helps babies and our species to survive.[2]

The good food of infancy is sweet: mother's milk. Milk from the breast is sweeter than milk from the bottle. Sweet milk and a sweet tooth help a baby learn to nurse. A sweet tooth has proved to be so useful for survival that evolution has fitted every child with one that functions perfectly at birth. Even before birth: the foetal sweet tooth works so well that a Dutch obstetrician used it to try to help pregnant women who were bloated with excessive amniotic fluid. He injected saccharine into the womb to induce the foetus to drink, so that the excessive fluid would pass from the foetus's body through the placenta into the mother's body, which would then expel it by urinating. The more saccharine he injected, the more the foetus drank. However, this treatment turned out to be temporary, because just as adults become sated with sweets, so did the foetus.[3]

Although Professor Machus relishes unsweetened espresso, as a boy he had childish tastes and perceptions. Indeed, he began life as an infant with infantile tastes and perceptions. His adult preferences must have somehow been built upon those. Physically, not just poetically, the child is father of the man.

To learn about the development of adult aesthetic preferences, we need to begin at their beginning. In our previous book, *The World of the Newborn*, we developed from the scientific literature a picture of what the world looks and sounds and feels and tastes like to a baby who has just been born. The world of the newborn is where our preferences begin to form, the world where we need to begin this discussion.[4]

This world we found to be chaotic, chaotic to an extreme. A table stands stolidly but a newborn may perceive it to be moving—until his mother picks him up and carries him around the room. As she does this, the table will slow down. Moreover, not only will the baby see the table, he may hear it and taste it too. Every time he closes and opens his eyes, visions and smells appear and disappear. When he falls asleep, he does not lose consciousness, he becomes conscious of different things.

At this time of his life a baby not only does not recognize things, he does not realize that there are things in the world that he might come to recognize. He does not even realize that there are things or a world. He has sensations, a profusion of sensations, but he can recognize very few of those sensations. His world is so confused and confusing that any sensation he manages to recognize will attract his attention. If his mother eats anise-flavoured sweets during the fortnight or so before his birth, he will likely recognize the smell of anise and turn his head toward it. This reaction is definitely not innate. The smell of anise causes most newborns to turn up their noses in apparent disgust.[5]

After birth, a repeated stimulus can generate not just recognition but also a preference. Babies do not usually seek out carrots but if a mother drinks carrot juice four days per week for the first two months she is nursing—only the first two months—then when her baby is six months old, he will usually prefer carrot-flavoured cereal to ordinary cereal. The flavour of carrots passes into the mother's milk, the baby comes to know the taste of carrots, he comes to expect the taste of carrots when food fills his mouth, and so he comes to feel more satisfaction when he tastes carrots than when he does not. This is the prototype of an aesthetic preference.[6]

However, it is quite a rudimentary prototype. It is a world away from the aesthetic preference of a sophisticated restaurant critic or even of a gastronomically naive adult. Not only is a baby not an adult, philosopher Machus can mount a powerful argument that a newborn baby is not yet a fully human being, that a newborn is merely the precursor of a human being. He can point out that the foetus just before birth is a larval creature living in a marine environment, a creature that takes oxygen and nourishment through an organ that does not exist in the adult form of the species—the equivalent of a tadpole. He can say that at birth a baby is equivalent to a tadpole that has just begun to breathe air. It is no more a human being, Machus can say, than a tadpole is a frog. He can argue that a newborn baby hardly even looks human, for its proportions are further from a nine-month-old's than a nine-month-old's proportions are from an adult's. He can also point out that a newborn baby exhibits no behaviour that is exclusively human or peculiarly human or even particularly human. In Aristotelian terms, the end (*telos*) of a newborn is to become human but its substance, essence and material are generically mammalian. In sum, Machus can say, there is no argument that a newborn baby is human save the argument that it will become so some day.

A philosophical argument like this would not go over well with many people. Professor Machus would never be employed by an evangelical college or St. Anybody's University. However, although Machus's colleagues might dispute his philosophy and his conclusions, they cannot gainsay the scientific evidence that a newborn's perceptions are radically different from an adult's perceptions or even from the perceptions of an older baby. Relatively few of us see music or taste the colour of the room. We cannot look at a newborn baby, see what he prefers, and assume that those preferences will develop into adult preferences through any simple process like elaboration. Indeed, we know that a newborn's preferences are *not* elaborated. An entirely new structure is built upon them, just as a medieval church is built upon a Roman foundation. All that the Roman foundation will have predetermined is the location of the walls.

Since aesthetic preferences are formed by the brain and within the brain, we need to begin by understanding some of the brain's functioning. Moreover, since we intend to root our understanding of aesthetics in the fundaments of basic science—of physics and biology—we must approach the brain at fundamental levels. That is what we are going to do in this chapter. We shall cover material that will seem far removed from aesthetics, and much of it will seem abstract and abstruse—if you have no background in science or mathematics, your head may reel—but please bear with us. This chapter is a necessary foundation, and its concepts will become clearer as we apply them and reapply them throughout the book.

Energy and Entropy

As civilized human beings we would like to believe that the main function of the brain is to think and feel, but it is not. The brain evolved to control the processing of energy. Every day each of us takes in and expends enough energy to heat sufficient water for a bath. The energy we acquire is mostly latent within chemicals that we ingest as food. The energy we expend takes many forms from flailing arms to radiating heat. Controlling the acquisition of energy—obtaining food and eating it—and controlling the expenditure of energy: this is the brain's primary job. A brain does come to think and to have aesthetic feelings and emotions, but as we shall see, thoughts and feelings are emergent phenomena that develop in different ways to different extents in different organisms.[7]

The brain is the control room of an energy-processing plant, and wires to and from it—nerves—run everywhere. Sensors react to minuscule changes in pressures, temperatures, and chemicals impinging upon the body. The reactions are electrochemical impulses that run through nerves into the brain. From the brain these impulses go back out to stimulate muscular contractions. The process works like a factory from 1950: sensors send signals to a bank of relays, the relays send signals to solenoids, solenoids control machines.

The processing controls of the human factory respond to infinitesimal amounts of energy disturbing electrons. This energy may be the pressure of something touching the skin, or the pressure of air vibrating against the eardrum, or the pressure of photons of light striking the back of the eye. Disturbed electrons set off a microscopic chemical reaction. This chemical reaction sets off more chemical reactions, which set off still more reactions, creating long chains of chemical reactions in various directions. Those chemical reactions pass along nerves into and through the brain, and then out of the brain through more nerves to muscles. The key factor here is that they are all chains of chemical reactions—organized reactions—not a disorganized mass of energy scattering everywhere.

The organizing principle of these reactions is built into the chemistry of individual nerve cells, of individual *neurons*. An electron ramming through neurons acts like a cop pushing through a crowd of people. He pushes his way through by shoving people to the left and right, which makes it easy for his partner to follow him, but pushing people sideways makes the crowd denser toward the sides, so the partner cannot easily deviate leftward or rightward. Neuronal traffic behaves similarly except that the pressures and crowds are atomic.

Note that consciousness is not needed for this. If you are in a crowd of people standing about an airport and policemen push through, you and your luggage will be shoved aside no matter whether you see them coming or not.

Note, too, that your luggage will never be pushed always and entirely out of everybody's way. No matter where in the airport your suitcase stands, eventually some clumsy oaf will barge into it with a luggage trolley. If it were to stand about the airport for a century or two, enough luggage trolleys would barge into it that eventually it would become battered to bits. To keep your suitcase from disintegrating would require occasional but continual repairs.

This illustrates one of the basic laws of physics, the second law of thermodynamics. This law holds that any form of organized energy will lose its organization unless some external force holds it together. Disorganized energy is called entropy, so a short form of this law is, "Entropy tends always to increase."

Or shorter still, "Things fall apart."

A bucket holding water resists the natural tendency of water to spill all over the ground: the bucket resists the water's entropy. The energy forming the resistance comes from the atomic forces forming material of the pail.

A man is not a pail but we can think of a man as a bag—a self-mending bag— that holds four gallons of water plus some shovelsful of chemicals. To be self-mending requires the bag to receive and deploy energy in complex and unpredictable ways. Organizing that energy is the function of the brain.

Adaptation

Imagine a balloon. The balloon is a membrane, a sheet of particles held together by internal atomic forces. Those forces form an elastic structure strong enough to resist the entropy of air under gentle pressure. A single-celled organism is comparable, except that it is filled with fluid and the pressures within the fluid are physiochemical.

When you hit a balloon, it rebounds off your hand mechanically. If it hits a wall, it rebounds off the wall mechanically, following the laws of physics. A single-celled organism functions comparably, except that it does not react mechanically, it reacts physiochemically.

A single-celled organism is a tropic creature. In this usage *tropic* is pronounced with a long *o*. The word comes from the Greek *trop*, a turning. *Tropic* with a short *o* denotes where the sun turns around during its annual meandering northward and southward.

In multicellular organisms, the individual cells always behave tropically, even in man. However, if you combine enough automata in the right way, you can end up with a device that behaves as though it has free will. Do plants turn toward the sun tropically or because they want to?

We shall not suggest either that plants have free will or that man does not. We do not want to argue with Professor Machus and for our purposes, the philosophical question does not matter. We are dealing in science, not philosophy. We observe that human bodies make a continuum of responses from simple and tropic to complex and adaptive. We also observe that human bodies combine these responses in ways that often form the appearance of free will. For us that is sufficient.

To the extent that an organism does not respond to things automatically, it responds adaptively—which brings us to babies again. If the gentle stroke of a hand causes a tropic creature to start, the same stroke will always cause it to start, but this does not happen with a newborn baby. To be sure, a baby is born with some reflexes and with many tropic functions in his innards, but his behavioural reflexes are weak, so much of a newborn's behaviour cannot be tropic. On the other hand, when a baby first encounters the world, neither can he have adapted to anything in it save a few flavours that may have passed into the womb and some aspects of his mother's voice.

Now remember our description of the newborn's world: a stream of incoherent sensation. Nothing exists save what is present, and a sight may taste different from a sound just smelled before. There is no world, just a mixture of sensations. To understand that there is a world beyond his sensations, the first thing a baby must do is come to recognize sensations he has encountered before. The mechanism of this recognition is chemical. When the brain is stimulated repeatedly, physiochemical reactions form neurochemical channels. Those channels control energy within the brain, lessening entropy.

This channelling permits us simultaneously to adapt to our environment yet be aware of it as well. Once a normal background forms channels, unexpected variations stand out.

Variations may portend trouble or may indicate food, so an adaptable animal must be able to discriminate helpful variations from harmful. Paradoxically, small variations matter more than large ones. Imagine that you are walking on the veldt and looking off into the distance. Halfway to the horizon you make out this scene. You must realize immediately that you are not seeing a tree stump. If you need to

wait until you can see it clearly as a lion, you will never see anything else again. For this reason, mechanisms of adaptation have evolved to enable slight variations from the background to be especially salient.

That, we shall see, is the fundamental principle of pleasure. Pleasure is the brain's response to a change from a pattern in a direction that experience has shown to be positive in some way. This mechanism begins with some of the simplest reflexes that keep the baby alive, it winds its way through sex and sensibility, and it ends with the most sophisticated forms of art.

Deterministic Chaos

This brings us to another paradox: aesthetic pursuits involve the appearance of choice and free will yet all evolve from the tropic functioning of cells. To understand how this might happen, consider a game of billiards. One ball bumps into another. Both balls rebound from the bumper in different directions, causing them to bump into others, which rebound into others in turn. This is organized motion. Usually the motion stops quickly because the balls and the felt absorb energy, but imagine that each billiard ball contains a source of energy, a source of energy just potent enough to compensate for the energy dissipated by compression and friction. Now the balls will continue to move about and bang into one another indefinitely. If you watch them, their motion will make no sense. It will look chaotic. However, each collision and rebound and new collision will follow predictable physical laws, the laws of action and reaction. The initial break will have started the balls in motion and determined all of the rest. The collisions will occur in an order that develops naturally from the first collision, naturally and ineluctably. It is