Natural Theology
or
Evidences of the Existence and Attributes of the Deity
collected from the appearances of nature

William Paley

1802

[Brackets] enclose editorial explanations. Small ·dots· enclose material that has been added, but can be read as though it were part of the original text. Occasional •bullets, and also indenting of passages that are not quotations, are meant as aids to grasping the structure of a sentence or a thought. In other texts on the website from which this one comes, four-point ellipses . . . . are used to indicate the omission of brief passages; in the present text such omissions are not noted, as there are too many of them. Paley was in many ways an excellent stylist, but he was enormously prolix, mostly through repetitions, which have been stripped out. Long omissions are reported between brackets in normal-sized type. —Paley provides dozens of references to works of anatomy, natural history, theology etc., which are omitted from the present version. —The division into numbered chapters is Paley's; some of the chapter-titles are not; and the division into unnumbered sections is not.

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Contents

Glossary

affect: As used in one paragraph on pages 75–76 this means 'be drawn to, have something like a desire for'. Paley seems to use it as the verb cognate with the noun 'appetency'.

appetency: A propensity or tendency to go after something. Broader in meaning than 'desire' or 'appetite', but sufficiently related to them for Paley to say on page 76 that the term can't be transferred from animals to plants.

art: Paley mainly uses this to refer to human skill, until page 44, after which the skill in question is sometimes God's or (the same thing, for Paley) nature's.

artificial: Made with skill. Quite often, the skill is God's.

artist: A human being who uses skill in making something. A watch-maker is an 'artist' even if there is nothing 'artistic', in our sense, about the watch. Similarly 'artificer'.

brute: sub-human animal, not necessarily 'brutal' or 'brutish' (as we would say).

contrivance: One of Paley's favourite words, it is equivalent to 'design'.

curious: Paley's meaning for this seems to be somewhere in the region of three of the OED's senses for it: 'exquisite, excellent, fine', 'interesting, noteworthy', 'deserving or arousing curiosity; strange, queer'.

elements: Paley uses this term mainly to refer to the traditional four: earth, air, fire, water. In chapter 21 ('Elements'), however, earth drops out; and both there and in chapter 17 light is included, as 'this new, this singular element'.

evil: bad. In early modern times it did not have as strenuous a meaning as it does today. Especially when used as a noun: 'the origin of evil' means 'the explanation of why there is anything bad in the universe'; a toothache would count as an evil.

faculty: Capacity, ability.

final cause: Goal, end aimed at, purpose. Paley uses the phrase quite often, but, oddly, not before page 37.

imperfection: When Paley speaks of the imperfection of some part of our knowledge (e.g. of chemistry) he means its incompleteness, its not yet being finished. Especially in chapter 7. In 'the evils of imperfection' (pages 88–89) the word means something more like what we mean by it today.

industry: work.

instrument: When on page 10 and elsewhere Paley insists that certain biological items are 'instruments', he means that they don't design anything; they are like the chisel, not the carpenter.

office: In Paley's day, a thing's 'office' was its role or function in some scheme of things. Similarly for the 'office' of a person.

original: An original feature of an organism is one that it had from the outset, not something it acquired later.

principle: Paley sometimes uses this word in a now-obsolete sense in which it means 'source', 'cause', 'driver', 'energizer', or the like. The phrase 'principle of order', which he mocks on pages 2 and 14, means 'something bringing it about that there is order in the world'.

probation: Testing someone's character, especially with a view to his fitness for the after-life.

second causes: intermediate causes, between God (the first cause) and whatever effects we are interested in.

station: Social standing, rank.

subservient: Serving as a means to an end (OED). Similarly 'subservience'.

1. The basic argument

Suppose that in crossing a meadow I pitched my foot against a stone, and were asked how the stone came to be there; I might answer that for all I knew to the contrary it had lain there for ever, and it might not be very easy to show the absurdity of this answer. But suppose I had found a watch on the ground, and it was asked how the watch happened to be in that place; I would hardly think of the answer that for all I knew it might have always been there. But why should this answer not serve for the watch as well as for the stone? For this and no other reason: when we inspect the watch we perceive (what we could not discover in the stone) •that its various parts are shaped and put together for a purpose, i.e. •that they are formed and adjusted so that they move, and that motion is regulated so as to point out the hour of the day; •that if the different parts had been different in shape, size, or relations to one another, either no motion would have occurred in the machine, or none that would have answered the use that is now served by it. To reckon up a few of the plainest of these parts, and of their offices [see Glossary], all tending to one result:

- •A cylindrical box containing a coiled elastic spring, which by its attempt to relax itself turns around the box.
- •A flexible chain communicating the action of the spring from the box to the fusee.
- •A series of wheels, the teeth of which engage with one another, conducting the motion from the fusee to the balance, and from the balance to the pointer; and at the same time, by the size and shape of those wheels, regulating that motion in such a way that an evenly moving pointer passes over a given space in a given time.
- •The wheels are made of brass in order to keep them from rust; the springs of steel, no other metal being so elastic.
- •Over the face of the watch there is placed a glass, a material employed in no other part of the work, its transparency being needed so that the hour could be seen without opening the case.

To see and understand all this requires an examination of the instrument and perhaps some previous knowledge of the subject; but once it has been observed and understood, the inference seems inevitable that **the watch must have had a maker**: there must have existed, at some time and some place an artificer or artificers who formed it for the purpose which we find it actually to answer, who understood its construction and designed its use.

(1) I do not think it would weaken the conclusion if we had never seen a watch made, had never known an artist [see Glossary] capable of making one, could not possibly carry out such a piece of workmanship ourselves or even understand how it was performed. All this is no more than what is true of some exquisite remains of ancient art, of some lost arts, and—to most people—of the more curious [see Glossary] productions of modern manufacture. Does one man in a million know how lathes are used to produce oval picture-frames? Ignorance of this kind raises our opinion of the unknown artist's skill if he *is* unknown, but it creates no doubt in our minds of the existence and agency of such an artist at some former time and in some place. Nor can I see that it makes any difference to the inference whether it concerns a human agent, an agent of a different species, or an agent possessing in some respects a different nature.

(2) Nor would it invalidate our conclusion if the watch sometimes went wrong or seldom went exactly right. The purpose of the machinery, the design, and the designer might be evident—and in the case of the watch *would* be evident—however we accounted for the irregularity of the movement, or whether we could account for it or not. A machine does not have to be perfect in order to show with what design it was made, let alone showing that it was made with some design.

(3) The argument would not be weakened if there were **(i)** a few parts of the watch concerning which we could not discover, or had not yet discovered, how they contributed to the general effect; or even **(ii)** some parts concerning which we could not ascertain whether they contributed to that effect at all. For, as regards **(i)**, if by the loss or disorder or decay of the parts in question the movement of the watch were stopped or disturbed or retarded, no doubt would remain in our minds as to the utility or intention of those parts, even if we could not investigate *how* the ultimate effect depended on their action or assistance; and the more complex the machine, the more likely this obscurity is to arise. As regards **(ii)** the supposition that there were parts that could be spared without prejudice to the movement of the watch, and that we had proved this by experiment: these superfluous parts, even if we were completely assured that they were such, would not cancel our reasoning concerning other parts. The indication of contrivance [see Glossary] remained, with respect to them, nearly as it was before.

(4) No man in his senses would think the existence of the watch accounted for by being told that it was one out of the possible combinations of material forms; that whatever he had found in that place must have contained *some* internal configuration, and that this configuration might as well be the structure now exhibited—namely of the works of a watch—as a different structure.

(5) Nor would it yield his inquiry more satisfaction to be told that there is in things a principle [see Glossary] of order that had disposed the parts of the watch into their present form and situation. He never knew a watch made by the principle of order; nor can he even form to himself an idea of what is meant by 'principle of order' other than the mind of the watch-maker.

(6) He would be surprised to hear that the mechanism of the watch was no proof of contrivance, only something that induces the mind to think so.

(7) . . . and not less surprised to be informed that the watch is nothing more than the result of the laws of metallic nature. It is a perversion of language to assign any *law* as the efficient, operative cause of anything. A law presupposes an agent, for it is only the way in which an agent proceeds; it implies a power, for it is the order according to which that power acts. This agent and this power are distinct from the law itself, and without them the law does nothing, is nothing. [Paley adds that the more familiar 'law of vegetable nature', 'law of animal nature', and 'law of nature' are just as disreputable as 'law of metallic nature' when any of these laws is taken to be the *cause* of something, leaving out agency and power.]

(8) Nor would our observer be driven out of his conclusion, or from his confidence in its truth, by being told that he knew nothing at all about the matter. He knows enough for his argument: he knows the usefulness of the end; he knows the subservience [see Glossary] and adaptation of the means to the end. These points being known, his ignorance of other points (or doubts concerning other points) do not affect the certainty of his reasoning. Awareness of knowing little need not make him distrust what he does know.

2. Watch producing watch

Continuing the basic argument: suppose now that the person who found the watch discovered later that in addition to all the properties he had observed it to have, it also had the unexpected property of producing in the course of its movement another watch like itself. Suppose, as is conceivable, that it contained within it a mechanism—a mould or a complex system of lathes, files, and other tools—evidently and separately calculated for this purpose. What effect ought this to have on his former conclusion?

(1) The first effect would be to increase his admiration of the contrivance, and his belief in the consummate skill of the contriver This new observation would give him nothing but an additional reason for doing what he had already done, namely for referring the construction of the watch to design and to supreme art. If, before this property had been noticed, that construction proved intention and art to have been employed in it, the proof would appear still stronger when he came to the knowledge of this further property, the crown and perfection of all the rest.

(2) He would reflect that although the watch before him was in some sense the *maker* of the watch that was fabricated in the course of its movements, this was in a very different sense from that in which, for instance, a carpenter is the *maker* of a chair, namely the author of its contrivance, the cause of the relation of its parts to their use. With respect to these, the first watch was no cause at all to the second: it was not the author of the constitution and order of the parts the new watch contained, or of the parts by the aid and instrumentality of which it was produced. We might possibly say, using words very broadly, that a river ground corn; but no broadness of language would allow us to say—and no stretch of conjecture could lead us to think—that the river built the mill, even if the mill was too ancient for us to know who the builder was. What the river does in the affair is just this: by the application of an unthinking impulse to a mechanism previously arranged—arranged independently of it, by something thinking—an effect is produced, namely the corn is ground. But the effect results from the arrangement. The force of the river cannot be said to be the cause or author of the effect, still less of the arrangement. The river's share in grinding the corn does not detract from the need for understanding and plan in the formation of the mill; and this applies to the watch's share in the production of the new watch, on the supposition we are now exploring.

(3) So even if it is now no longer probable that the individual watch that our observer found was made •immediately by the hand of an artificer, this has no effect on the inference that an artificer was •originally involved in the production. The argument from design remains as it was. Marks of design and contrivance are no more accounted for now than before. We can ask for the cause of a thing's different properties—of its colour, its hardness, its heat—and these causes may be all different. We are now asking for the cause of that subservience to a use, that relation to an end, that we saw in the watch in our hand; and this question is not answered by the statement that a preceding watch produced it. There can't be

- •design without a designer,
- •contrivance without a contriver,
- •order without choice,
- •arrangement without anything capable of arranging,
- •subservience and relation to a purpose without something that could intend a purpose,
- •means suitable to an end, and executing their office in accomplishing that end, without the end having been contemplated, or the means made to fit it.

Arrangement, disposition of parts, subservience of means to an end, relation of instruments to a use, imply the presence of intelligence and mind. No-one, therefore, can rationally believe that the unthinking inanimate watch from which the watch before us issued •was the proper cause of the mechanism we so much admire in it, i.e. •could be truly said to have constructed the instrument, disposed its parts, assigned their office, determined their order, action, and mutual dependency, combined their various motions into one result that is connected with the utilities of other beings. So all these properties are as much unaccounted for as they were before.

(4) Nor is anything gained by running the difficulty further back, i.e. by supposing this watch to have been produced from another watch, that from a former one, and so on indefinitely. However far back we go, that will bring us no nearer to any satisfaction on the subject. Contrivance is still not accounted for; we still lack a contriver; a designing mind is not provided by this supposition, nor is it shown not to be needed. If the difficulty grew less the further back we went, we might by going back indefinitely remove it altogether. Where as we increase the number of terms there is a tendency (or continual approach) towards a limit, there by supposing the number of terms to be what is called 'infinite' we may conceive the limit to be reached; but where there is no such tendency or approach, nothing is achieved by lengthening the series. There is no difference in our present context (whatever there may be in many others) between a finite series and an infinite series; a chain composed of an infinite number of links can no more support itself than can a chain composed of a finite number of links. And of this we are assured (though we never can have tried the experiment), because by increasing the number of links from 10 to 100, say, or from 100 to 1,000, we do not observe the smallest tendency (make the smallest approach) towards self-support. The machine we are inspecting demonstrates by its construction *contrivance* and *design*. contrivance must have had a contriver; design, a designer; whether the machine immediately came from another machine or not. [He spells the point out again: however far back we go in the sequence of machine-producing machines, the requirement for a designer remains in full force.]

The question is not simply 'How did the first watch come into existence?'. It may be claimed that *that* question is disposed of by supposing the series of watch-producing watches to have been infinite, and consequently to have had no first member for which a cause must be provided. This might have been nearly the state of the question if nothing had been before us but an unorganised, unmechanised substance with no indication of contrivance. It might be difficult to show that this could not have existed from eternity, either •in succession (if unorganised bodies could arise from one another, which I do not think they could) or •by individual perpetuity [i.e. by there being one body that has always existed, never began]. But that is not the question now. The watch we are examining manifests contrivance, design; an end, a purpose; means for the end, adaptation to the purpose. And the question that irresistibly presses on our thoughts concerns the origin of this contrivance and design. The thing required is the intending mind, the adapting hand, the intelligence by which that hand was directed; and this demand is not shaken off by increasing a number or succession of substances, even by increasing that number to infinity. That increase still leaves us with contrivance but no contriver, proofs of design but no designer.

(5) Our observer would also reflect that the maker of the watch before him was really the maker of every watch produced from it. As between

(i) making another watch with his own hands, by the mediation of files, lathes, chisels, etc. and

(ii) disposing, fixing, and inserting these instruments in the body of the watch already made in such a way as to produce a new watch in the course of the movements he had given to the old one

there is no difference except that **(ii)** manifests a more exquisite skill. As for the view that the discovery of the watch-producing watch, rather than increasing our admiration of the skill involved, should turn us round to the opposite conclusion that no art or skill has been concerned in the business; it is simply absurd. Yet this is atheism.

3. Applying the argument: eye & telescope

This is atheism: for every indication of contrivance, every manifestation of design that existed in the watch exists in the works of nature; with the difference that in nature they are incalculably greater. I mean that the contrivances of nature surpass the contrivances of art in the complexity, subtlety and curiosity of the mechanism; and in their number and variety; yet in many cases they are at least as obviously •mechanical, •contrivances, •adjusted to their end, as are the most perfect productions of human ingenuity.

I know no better method of introducing so large a subject than to compare one single thing with another, e.g. an eye with a telescope. As far as the examination of the instrument goes, there is precisely the same proof that the eye was made for vision as that the telescope was made for assisting it. They are made on the same principles, both being adjusted to the laws governing the transmission and refraction of light. Those laws, whatever their origin, are *fixed*, and the construction in both cases is adapted to them. For instance:

> These laws require that if the same effect is to be produced, the rays of light passing from water into the eye should be refracted by a more convex surface than when passing out of air into the eye. And we find that the crystalline lens in the eye of a fish is much rounder than in the eye of terrestrial animals.

What plainer manifestation of design can there be than this difference? What more could an instrument-maker have done to show his knowledge of his principle, his application of that knowledge, his suiting of his means to his end?

To some it may appear that the eye is not comparable with the telescope because one is a perceiving organ and the other an unperceiving instrument. In fact they are both instruments; and the kind of mechanism employed in both is the same. ·I shall now show this·.

Observe what the constitution of the eye is. To produce clear vision an image or picture of the object must be formed at the bottom of the eye. Why this is required, or how the picture is connected with the sensation may be difficult or even impossible for us to find out; but that is irrelevant to the present question. It may be true that in some cases we trace mechanical contrivance a certain way and then come to something that is not mechanical, or that is inscrutable; but this does not affect the certainty of our investigation as far as it has gone. The difference between an animal and an automatic statue [= 'robot'] is this:

- •in the animal we trace the mechanism to a certain point and then we are stopped; either the mechanism becomes too subtle for our discernment, or something other than the known laws of mechanism comes to be involved, whereas
- •in the automaton, for the few motions of which it is capable, we trace the mechanism throughout.

But up to that limit, the reasoning is as clear and certain in the one case as in the other. In the example before us, it is a matter of certainty—demonstrated by experience and observation—that the formation of an image at the bottom of the eye is necessary to perfect vision. The formation of such an image being necessary (no matter how) to the exercise of the sense of sight, the apparatus by which it is formed is put together not only with infinitely more art but on the self-same principles of art as in the telescope or the camera obscura. The perception arising *from* the image is not in question here; for the production *of* the image these are instruments of the same kind: they are alike in their end and the means to it. The lenses of the telescope and the humours of the eye are exactly alike in their shape, their position, and their power to bring each pencil of light-rays to a point at the right distance from the lens, namely (in the eye) at the exact place where the membrane is spread to receive it. With such close similarity, how is it possible to exclude contrivance from the one yet to acknowledge the proof of contrivance having been employed, as the plainest and clearest of all propositions, in the other?

The resemblance between the two cases obtains in more points than those I have mentioned, indeed more than we are, on our first view of the subject, even aware of. In dioptric telescopes, there is this imperfection: pencils of light in passing through glass lenses are separated into different colours, thereby tinting the object, especially its edges, as if it were viewed through a prism. A correction of this inconvenience was long desired by opticians. At last it occurred to one sagacious optician to inquire how this matter was managed in the eye, where there was exactly the same difficulty to contend with as in the telescope. He found that in the eye the trouble was fixed by combining lenses composed of different substances, i.e. substances with different refracting powers. He took his hint, and produced a correction of the defect by imitating, in glasses made from different materials, the effects of the different humours through which the light-rays pass en route to the bottom of the eye. Could this be in the eye without purpose—this system that suggested to the optician the only effective means of attaining that purpose?

The eye's superiority to the telescope

There are also ways in which the eye is superior to the telescope. Two things were needed for the eye that were not needed (at least in the same degree) for the telescope: the adaptation of the organ **(1)** to different degrees of light and **(2)** to the vast diversity of distance—from a few inches to as many miles—at which objects are viewed by the naked eye. These are not difficulties for the maker of the telescope. He wants all the light he can get; and he never directs his instrument to objects near at hand. In the eye, each difficulty is provided for by a subtle and appropriate mechanism.

(1) In order to exclude excess of light when it is excessive, and to make objects visible when there is less light, the hole or aperture in the eye through which the light enters is so formed as to contract or dilate itself for the purpose of admitting more or fewer rays at the same time. The chamber of the eye is a camera obscura which when the light is too small can enlarge its opening, when too strong can again contract it, without any assistance but that of its own exquisite machinery. Observe also that in the human subject this hole in the eye (we call it the 'pupil') through all its changes of size retains its exact circular shape. If an artist [see Glossary] tries to achieve this he will find that his threads and strings must be disposed with great care and contrivance, to make a circle that continually changes its diameter but keeps its shape. This is done in the eye by an application of fibres similar in their position and action to what an artist would have to employ if he had the same piece of workmanship to perform.

(2) The second difficulty was that of suiting the eye to the perception of objects near at hand and of objects at a considerable distance. According to the principles of optics—i.e. the fixed laws by which the transmission of light is regulated—this could not be done without an alteration in the eye itself, affecting the angles to one another at which the light-rays reached it. Rays issuing from points close to the eye must enter the eye in a spreading or diverging order; rays from objects situated much further away arrive at the eye nearly parallel; the two cannot—by the same optical instrument in the same state—be brought to a point, i.e. be made to form an image, in the same place. Well, it has recently been found that when the eye is directed to a near object three changes occur that jointly contribute to the adjustment required. •The cornea or outermost coat of the eye is made more round and prominent; •the crystalline lens underneath is pushed forward; and •the axis of vision (as the depth of the eye is called) is elongated. These changes in the eye vary its power over the rays of light in such a way as to produce exactly the desired effect, namely the formation of an image on the retina, whether the rays come to the eye angled to one another or parallel to one another. Can anything be more decisive of contrivance than this is? The most secret laws of optics must have been known to the author of a structure having such a capacity for change.

[Paley exclaims about how these wonders are present in the eyes of a new-born child; then describe variations in different animal species, reflecting differences in needs and life-styles. E.g. birds' eyes get special help to make the changes needed for seeing things very close up and very far away; comparable points about fishes, and eels. Then:]

Other wonders of the eye

In considering vision as achieved by the means of an image formed at the bottom of the eye, we must wonder at the smallness yet correctness of the picture, the subtlety of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects that it contains are all preserved, all distinguished in their sizes, positions, shapes, colours. The prospect from Hampstead hill is compressed into the area of a sixpence, yet represented in detail. A stage coach travelling at its ordinary speed for half an hour passes, in the eye, over only one-twelfth of an inch; yet this change of place in the image is distinctly perceived throughout its whole progress, for it is only by means of that perception that the motion of the coach itself is made sensible to the eye. If anything can lessen our admiration of the smallness of the visual tablet compared with the extent of vision, it is the reflection—to which we are constantly led by the view of nature—that in the hands of the Creator the difference between great and little is nothing.

Sturmius held that the examination of the eye was a cure for atheism. Everything belonging to it and about it shows an extraordinary degree of care, an anxiety for its preservation, because of its value and its tenderness. It is lodged in a strong, deep, bony socket, composed by the junction of seven different bones, hollowed out at their edges. Within this socket it is embedded in fat, of all animal substances the best adapted both to its repose and its motion. It is sheltered by the eyebrows; an arch of hair which like a thatched penthouse prevents the sweat and moisture of the forehead from running down into it.

But it is still better protected by its lid. Of the superficial parts of the animal frame, I know none which in its office and structure is more deserving of attention than the eyelid. It defends the eye; it wipes it; it closes it in sleep. Does any work of art exhibit purposes more evident than the ones the eyelid fulfils? or a more intelligible, more appropriate, or more mechanical apparatus for achieving those purposes? If it is overlooked by the observer of nature, that can only be because it is obvious and familiar. This is a tendency to be guarded against.

[Paley now **(i)** writes for half a page about the tear-glands' role in 'keeping the eye moist and clean', which fish do not have because they do not need it; and **(ii)** devotes two pages to 'that most exquisite of all contrivances, the nictitating membrane, which is found in the eyes of birds and of many quadrupeds', its role being to spread tears over the eye and also defend it from sudden injuries. He at length describes and praises the mechanism by which this works; and then moves on to a good theological question.]

Why would an omnipotent God make mechanisms?

One question may have dwelt in the reader's mind while reading these observations, namely *Why did not the Deity give the animal the faculty* [see Glossary] *of vision at once?* Why this circuitous perception?

> The employment of so many means: an element provided for the purpose reflected from opaque substances and refracted through transparent ones, both according to precise laws; then a complex organ, an intricate and artificial [see Glossary] apparatus, in order—by the operation of this element and in conformity with these laws—to produce an image on a membrane communicating with the brain?

Why all this? Why make the difficulty in order to overcome it? If what was wanted was for the animal to perceive objects in some way other than by touch, or to perceive objects that lay out of the reach of that sense, could not a simple volition of the Creator have conferred that ability? Why resort to contrivance where power is omnipotent? contrivance, by its very definition and nature, is the refuge of imperfection. To have recourse to expedients implies difficulty, impediment, restraint, defect of power. This question arises for the other senses as well as sight; to the general functions of animal life, as nutrition, secretion, respiration, to the economy of vegetables, and indeed to almost all the operations of nature. So the question is of very wide extent. Among other answers that may be given to it—beside ones of which probably we are ignorant—one is this: *It is only by the display of contrivance that the existence, agency, and wisdom of the Deity could be testified to his rational creatures.* This is the ladder by which we ascend to all the knowledge of our Creator that we have, so far as it depends on the phenomena, the works of nature. Take away this and you deprive us of every subject of observation and ground of reasoning—I mean as our rational faculties are formed at present. Whatever is done, God could have done without the intervention of instruments or means; but it is in the construction of instruments, in the choice and adaptation of means, that a creative intelligence is seen. This is what constitutes the order and beauty of the universe. God, therefore, has chosen to prescribe limits to his own power, and to achieve his end within those limits. The general laws of matter perhaps set these limits:

- its inertia, its re-action,
- the laws governing the communication of motion,
- the refraction and reflection of light,
- the constitution of fluids, non-elastic and elastic,
- the transmission of sound through the latter,
- the laws of magnetism, of electricity,
- and probably other laws not yet discovered.

These are general laws; and when a particular purpose is to be effected it is not by making a new law, or suspending the old ones, or by making them wind and bend and yield to the occasion (for nature with great steadiness adheres to and supports them). Rather, the purpose is achieved, as we have seen in the eye, by the interposition of an apparatus that corresponds to these laws and satisfies the need that results from them. As I have said, therefore, God prescribes limits to •his power so as to make room for the exercise—and thereby exhibit demonstrations of—•his wisdom. It is as though one Being fixed certain rules and provided certain materials; and then gave another Being the task of drawing forth a creation out of these materials in obedience to these rules; a supposition which obviously leaves room for contrivance and indeed creates a necessity for it. I do not advance this as a doctrine either of philosophy or of religion; but I say that the subject can safely be looked at in this way, because the Deity acting himself by general laws will have the same effect on our reasoning as if he had prescribed these laws to another. It has been said that the problem of creation was: ‘Attraction and matter being given, to make a world out of them’; and the explanation I have just given implies that this statement perhaps does not convey a false idea.

I have chosen the eye as an instance on which to rest the argument of this chapter. Some single example was to be proposed: and the eye offered itself under the advantage of admitting of a strict comparison with optical instruments. The ear is probably as artificially and mechanically adapted to its office as the eye is. But we know less about it: we do not so well understand the action, the use, or the mutual dependency of its internal parts. Its general form, however, both external and internal, is sufficient to show that it is an instrument adapted to the reception of sound; that is to say, already knowing that sound consists in pulses of the air, we perceive in the structure of the ear a suitableness to receive impressions from this kind of action and to propagate these to the brain. [Paley continues thus for several pages.]

4. The succession of plants and animals

Animals are the offspring of preceding animals, but this does not account for the contrivance [see Glossary] of the eye or ear; any more than—on the chapter 2 supposition—the production of a watch by the motion and mechanism of a former watch would account for the skill and intention evidenced in the watch so produced. I do insist on the correctness of this comparison: it holds for every kind of species propagation; whatever was true of the watch on the above-mentioned supposition is true of plants and animals.

(1) To begin with plants: can it be doubted that the seed contains a particular organisation, whatever its details may be, that is suited to the germination of a new plant? Has the plant that produced the seed anything more to do with that organisation than the watch would have to do with the structure of the watch that it mechanically produced? I mean, has it anything to do with the *contrivance*? Can any distinction be assigned between the producing watch and the producing plant; both passive, unconscious substances; both by the organisation that was given to them producing their like, without understanding or design; both, that is, *instruments*?

(2) From plants we may proceed to oviparous animals, from seeds to eggs. The bird has no more concern in the formation of the egg she lays than the plant has in that of the seed it drops. The internal constitution of the egg is as much a secret to the hen as if the hen were inanimate.

Her will cannot change a single feather of the chick. She can neither foresee nor determine of which sex her brood will be, or how many of either. So far from adapting the means, therefore, she does not know in advance what the effect will be. If concealed within that smooth shell there is a provision and a preparation for the production and nourishment of a new animal, they are not of her providing or preparing; if there is contrivance, it is none of hers. So the differences between the animal and the plant are irrelevant to my topic. Neither the one nor the other has to its offspring the sort of relation that a joiner does to the chair he makes. But *that* relation between cause and effect is what we want, to account for the suitableness of means to an end, the fitting of one thing to another; and this cause the parent plant or animal does not supply.

Notice also that the apparatus employed exhibits no resemblance to the thing produced, and are analogous in this respect to instruments [see Glossary] and tools of art. The filaments, anthers and stigmata of flowers are no more like the young plant (or even the seed) formed by their intervention than a chisel or a plane is like a table or chair. What, then, are the filaments etc. of plants but *instruments* strictly so called?

(3) We may advance from animals that bring forth eggs to ones that bring forth their young alive, and of these moving up the scale from brutes [see Glossary] to the human species, without perceiving any alteration in the terms of the comparison. The rational animal does not produce its offspring with more certainty or success than the irrational animal, a man than a quadruped, a quadruped than a bird. So rationality has nothing to do in the business. The parent is the cause of his offspring in the same sense as that in which a gardener is the cause of the tulip that grows on his parterre, and in no other. We admire the flower; we examine the plant; we perceive the conduciveness of many of its parts to their end and office; we observe a provision for its nourishment, growth, protection, and fecundity; but we never think of the gardener in all this, though it may be true that without the gardener we would not have had the tulip. The human parent is not the contriver of the structure of the offspring, as is shown by his state of mind: he is in total ignorance of why what is produced took its present form rather than any other; he is astonished by the effect. So we can no more look to •the intelligence of the parent animal for a cause of the means-end relation we see in the procreated body than we can refer the internal conformation of an acorn to •the intelligence of the oak from which it dropped, or the structure of the watch to •the intelligence of the watch that produced it. So far as this argument is concerned, there is no difference between an intelligence that is not exerted and an intelligence that does not exist.

5. Seven more points

Everything I said in chapter 1 about the watch can be repeated with strict propriety about the eye, about animals, about plants, indeed about all the organised parts of the works of nature. Thus:-

(1) When we are inquiring simply into whether something had an intelligent creator, there may be a considerable degree of imperfection, inaccuracy, liability to disorder, occasional irregularities, without bringing any doubt into the question; just as a watch may frequently go wrong, seldom perhaps exactly right; may be faulty in some parts, defective in some; without causing the slightest suspicion that it is not a watch, was not made, or was not made for the purpose ascribed to it. [Paley describes some of the moves we can make in such a case to prevent these faults from counting against 'the skill of the artist', and then sets all this aside.] These are different questions from the question of the artist's existence, i.e. of whether the thing before us is a work of art or not. Similarly with the works of nature: irregularities and imperfections are of little or no weight in considering the question of the existence of a Creator. When the question concerns his attributes, they *are* of weight; but [and then he lays out reasons why we should conclude that the 'apparent blemishes'] ought to be referred to some cause, though we are ignorant of it, other than defect of knowledge or of benevolence in the author.

(2) There may be also parts of plants and animals of which the **(a)** operation or the **(b)** use is unknown. These are different cases, for the operation may be unknown while the use is certain. **(a)** Thus it is with the lungs of animals. We are not acquainted with the action of the air on the blood, or with how that action is communicated by the lungs; but we find that a very short suspension of the lungs' office [see Glossary] destroys the life of the animal. So this is a case where we know the use—indeed, experience the necessity—of the organ, though we are ignorant of its operation. Somewhat similarly with the lymphatic system. **(b)** There may also be examples of the second kind, where not only the operation is unknown but experiments seem to show that the part is not necessary, or leave a doubt as to how far it is even useful to the plant or animal in which it is found. This is said to be the case with the spleen, which has been extracted from dogs without any perceptible injury to their vital functions.

Instances where **(a)** we cannot explain the operation may be numerous, for they will be so in proportion to our ignorance. They will be more or fewer to different persons, and in different stages of science. Every improvement of knowledge reduces their number; hardly a year goes by when some previously undiscovered and probably unsuspected operation or mode of operation does not come to light. Instances where **(b)** the part appears to be totally useless are extremely rare, I believe. [And, he goes on to say, it remains to be soundly shown that there are *any* such, concluding that even if it *were* shown,] these superfluous parts do not negate my reasoning concerning the parts that are useful, and of which we know the use. With respect to them, the indication of contrivance remains as it was before.

(3) One atheistic way of replying to my observations on the works of nature, and to the proofs of a Deity that I think I perceive in them, is to say:

> Everything we see must necessarily have had *some* form, and it might as well be its present form as any other.

Let us now apply this answer to the eye, as I did before to the watch. Something must have occupied that place in the animal's head; must have filled up, we will say, that socket. We will say also that it must have been of the sort we call 'animal substance', such as flesh, bone, membrane, cartilage, etc. But that it should have been an eye, knowing as we do what an eye comprehends—namely that it should have consisted of

- a series of transparent lenses,
- a black cloth or canvas spread out behind these lenses, so as to receive the image formed by pencils of light transmitted through them,
- a large nerve connecting this membrane with the brain, without which the action of light on the membrane would be lost to the purposes of sensation—

and that this fortunate conformation of parts should have been found in thousands of species of animals, that all this should have taken place, merely because something must have occupied those points in every animal's forehead—or that all this should be thought to be accounted for by the short answer that ‘whatever was there must have had some form or other’, is too absurd for me to make it more so! Indeed, it fails even when applied to appearances of organisation far short of those of the eye, such as we observe in fossil shells, petrified bones and the like, which may seem accidental enough in respect of utility or of the situation they are found in. It is not accounting even for these things to say that (for instance) the stone that is shown to us must have had *some* internal conformation or other. Nor does it mend the answer to add, with respect to the singularity of the conformation, that after the event it is no longer to be computed what the chances were against it. This is *always* to be computed when the question concerns whether a useful or imitative conformation is the product of chance. I desire no greater certainty in reasoning than that by which chance is excluded from the present disposition of the natural world. Universal experience is against it. What does chance ever do for us? In the human body, for instance, chance—i.e. the operation of causes without design—may produce a wen, a wart, a mole, a pimple, but never an eye. Among inanimate substances, a clod, a pebble, a liquid drop might be; but chance never created a watch, a telescope, an organised body of any kind, answering a valuable purpose by a complicated mechanism.

(4) Another answer, which has the same effect as resolving things into chance, says •that every animal and every plant, indeed every organised part thereof (such as the animal eye), are only some of the possible varieties of being that the lapse of infinite ages has brought into existence; and •that the present world is what is left of that variety, millions of other species having perished because their constitutions did not enable them to survive, or to propagate. Now, nothing we observe in the works of nature supports this conjecture; no such energy operates as that which is here supposed, which should be constantly pushing new varieties of beings into existence. Nor is there any evidence that every possible combination of vegetable or animal structure has formerly been tried. Multitudes of conformations of vegetables and animals may be conceived as capable of surviving and propagating that yet do not exist. We might have nations of human beings without nails on their fingers, with more or fewer fingers and toes than ten, some with one eye, others with one ear, with one nostril, or without the sense of smelling at all. No reason can be given why, if these lost species ever existed, they have now disappeared. But if all possible existences have been tried, they must have formed part of the catalogue.

Moreover, the division of organised substances into animals and vegetables, and the further distribution of each into genera and species—which is not an arbitrary act of the mind but based on the order that prevails in external nature—appears to me to contradict the supposition that the present world is the remains of an indefinite variety of existences, a variety that rejects all plan. The hypothesis says that every possible variety of being has somehow found its way into existence at some time, and that the badly formed ones perished; but it does not explain how or why the survivors should be cast into regular classes, as we see that plants and animals are; or rather the hypothesis is inconsistent with this phenomenon.

The hypothesis hardly deserves this much consideration. If someone told us that

> —because we had never seen watches, telescopes, stocking-mills, steam-engines, etc. made, did not know how they were made, and could not prove by testimony when or by whom they were made—

the curious [see Glossary] structures of these machines are to be explained thus:

> A mass of metals and other materials ran when melted into all possible shapes, and combined themselves in all possible forms and proportions; and the things that we see are merely the surviving stock of a magazine which, at one time or other, has contained every mechanism, useful, and useless, convenient and inconvenient, into which such like materials could be thrown,

what would we think of this? I cannot distinguish the hypothesis as applied to the works of nature from this solution as applied to a collection of machines, which no one would accept.

(5) To the marks of contrivance discoverable in animal bodies, and to the argument from these to the existence of a designing Creator, some have tried to give this turn:

> the parts were not intended for the use; the use arose out of the parts.

Well, a cabinet-maker rubs his mahogany with fish-skin, but no-one would say that the skin of the dog-fish was made rough and granulated so that cabinet-makers could use it for polishing wood; so the distinction is intelligible. But I think there is very little place for it in the works of nature. When roundly and generally affirmed of them, as it has sometimes been, it is analogous to this:

> *All* the implements of the cabinet-maker's workshop were substances accidentally configurated, which he had picked up and converted to his use; his adzes, saws, planes and gimlets were not made to work on wood with, but once they had been made—no matter with what purpose, if any—the cabinet-maker saw that they were applicable to his purpose, and turned them to account.

(a) And when this solution is applied to the parts of animals whose action does not depend on the will of the animal, it is even more evidently absurd. Is it possible to believe that the eye was formed without any regard to vision; that it was the animal itself which discovered that it would serve to see with, and that the use of the eye as an organ of sight resulted from the animal's application of this discovery? The same question may be asked of the ear, and of all the sense-organs. None of the senses fundamentally depend on the animal's choice or, therefore, on its sagacity or its experience. It is the impression objects make on the sense-organs that constitutes their use. In receiving that impression the animal is passive. It may bring objects within reach of the sense-organ; it may select these objects; but over the impression itself it has no power, or very little.

(b) There are many parts of animal bodies that seem to depend on the will of the animal in a greater degree than the senses do, and yet with respect to which this solution is equally unsatisfactory. Faced with a choice between these:

- **(i)** Teeth were made expressly for chewing food, feet for walking, hands for holding;
- **(ii)** Teeth etc. being as they are and being in fact in the animal's possession, its own ingenuity taught it that they were usable for these purposes, though no such purposes were contemplated in their formation;

no reasonable mind can hesitate in choosing **(i)**.

(c) The only thing that seems reasonable in this way of looking at things is this:

> In some cases the organisation seems to determine the habits of the animal, and its choice of a particular mode of life; and this could be called, in a certain sense, 'the use arising out of the part.'

However, in every such case we can say that the organisation determines the animal to habits beneficial and salutary to itself, and that this effect would not follow so regularly if the various organisations did not have a concerted and contrived relation to the substance by which the animal was surrounded. The web-foot determines the duck to swim, you say; but what use would that be if there were no water to swim in? The peculiar conformation of the bill, tongue and claws of the woodpecker determines that bird to search for his food among the insects lodged in the wood of decayed trees; but what would this profit it if there were no decayed trees with insects under their bark? The proboscis the bee is provided with determines him to seek for honey; but what would that signify if flowers supplied none? Faculties [see Glossary] thrown down on animals at random, without reference to the objects amidst which they are placed, would not provide them with the benefits that we see; and if there *is* that reference, there is intention.

(d) Lastly; the solution fails for plants, whose parts correspond to their uses with no input from the plant's will.

(6) Others have chosen to refer everything to a principle [see Glossary] of order in nature. That is their phrase, 'a principle of order'; but what this refers to other than an intelligent Creator has not been explained by definition or example; and without such explanation it seems to be a mere substitution of words for reasons, names for causes. *Order* is only the adaptation of means to an end; so a principle of it can only be the mind and intention that so adapts them. And if it can be explained in some other sense, is there any experience, any analogy, to sustain it? Was a watch ever produced by a principle of order? and why might not a watch be so produced as well as an eye?

Furthermore, a principle of order, acting blindly and without choice, is negated by the fact that order is not

- universal, which it would be if it issued from a constant and necessary principle, or
- indiscriminate, which it would be if it issued from an unthinking principle.

Where order is wanted, there we find it; where order is not wanted, i.e. where it would be useless if it did exist, there we do not find it. In the structure of the eye, in the shape and position of its various parts, the most exact order is maintained. In the forms of rocks and mountains, in shape of bays and promontories in the coasts of continents and islands, no order is perceived, because it would have been superfluous. No useful purpose would have arisen from moulding rocks and mountains into regular solids bounding the channel of the ocean by geometrical curves.

(7) Lastly, the confidence we place in our observations on the works of nature, in the marks we discover of contrivance, choice and design, and in our reasoning on the proofs provided us, ought not to be shaken—as some do try to shake it—by pointing to the general imperfection [see Glossary] of our knowledge of nature. In many cases this consideration ought not to affect us even when it respects some parts of the subject immediately under our notice. True strength of understanding consists in not allowing what we know to be disturbed by what we do not know. If we perceive a useful end, and means adapted to that end, we perceive enough for our conclusion; if these things are clear, no matter what is obscure, the argument is finished. If the usefulness of vision to the animal that has it, and the adaptation of the eye to this office [see Glossary] is evident and certain, ought the inference we draw from these premises to be prejudiced by the fact that we cannot explain the use of the spleen? Indeed, if there are parts of the eye manifestly suited to the forming of an image by the refraction of rays of light, the proof these provide of design and of a designer is not affected by there being *other* parts of the same eye whose agency or effect we can give no account of. Analogously, we would not and should not be inclined to doubt the purpose for which a telescope was constructed, or whether it was constructed at all, because it had certain screws and pins whose use or action we did not comprehend. I take this confidence-shaking move to be a general way of infusing doubts and scruples into the mind, to remind it of its own ignorance, its own incompetence; to tell us that on these subjects we know little, and that little imperfectly, or rather than we don't properly *know* anything about the matter. These suggestions sometimes produce a general distrust of our faculties and our conclusions, but this is unfounded. Before we yield in any particular instance to the scepticism that this sort of insinuation would induce, we ought to ascertain whether our ignorance or doubt concern the precise points on which our conclusion rests. Our ignorance of *other* points may be of no consequence to our argument, even if they are in various respects points of great importance. A sound reasoner removes from his consideration not only what he knows but also what he does *not* know regarding matters not strictly connected with his argument, i.e. not forming the very steps of his deduction.

6. The argument is cumulative

If the eye were the only example of contrivance in the world, that alone would be sufficient to support the conclusion I draw from it, regarding the necessity of an intelligent Creator. It could never be got rid of, because it could not be accounted for by any other supposition that did not contradict all our principles of knowledge. [Paley then re-states the relevant details concerning the eye, and says that they 'bear down all doubt' about the eye's having been designed.] And what I wish to observe in this chapter is that if other parts of nature were inaccessible to our inquiries—even if they presented to us nothing but disorder and confusion—the validity of this example would remain the same. If there were only one watch in the world, it would not be less certain that it had a maker. The proof is not a conclusion that lies at the end of a chain of reasoning, in which each instance of contrivance is only a link so that if one link fails the whole chain fails. Rather, a complete argument is separately supplied by every separate example. An error in stating an example affects only that example. The argument is *cumulative*, in the fullest sense of that term. The eye proves it without the ear; the ear without the eye. The proof in each example is complete; for when the design of the part, and the conduciveness of its structure to that design is shown, the mind may set itself at rest; no future consideration can detract anything from the force of the example.

7. The mechanical/non-mechanical distinction

In distinguishing the mechanical parts and processes of animals and vegetables from their non-mechanical parts and processes, I am not backing off from the thesis that

- every part of an animal or vegetable has proceeded from a contriving mind; that
- every part is constructed with a view to its proper end and purpose; and that
- every part is so constructed as to achieve its purpose while operating according to the relevant laws.

The point of the distinction is rather this: these laws themselves are not in all cases equally understood, or—what amounts to nearly the same thing—are not equally exemplified in simpler processes and simpler machines; ·and it is only when they *are* thus understood and exemplified that we call the processes they govern 'mechanical'·.

For instance: the principle [see Glossary] that drives muscular contractions, whether by an act of the will or by involuntary irritation, is wholly unknown to us. We know nothing of the substance employed or of the laws that regulate its action. We see nothing similar to this contraction in any machine we can make or any process we can execute. So far (it is confessed) we are in ignorance, but no further; ·and we label this principle '**non-mechanical**'·. Given this power and principle, the collocation of the fibres to receive the principle—the disposition of the muscles for the use and application of the power—is **mechanical**, and is as intelligible as the wires and strings by which a puppet is moved.

The nervous influence by which the middle of the muscle is swelled is not mechanical. We see the usefulness of the effect, but not the preparation of the means by which it is produced. But obscurity regarding the origin of muscular motion brings no doubtfulness into our observations regarding the motion itself:

- **(a)** the constitution of the muscle, such that the swelling of the middle part is necessarily and mechanically followed by a contraction of the tendons;
- **(b)** the astonishingly great number and variety of the muscles and the corresponding number and variety of useful powers they provide the animal with;
- **(c)** the wise and well-contrived disposition of each muscle for its specific purpose.

[He goes into details regarding **(c)**.] All this is mechanical, and is as accessible to inspection, as capable of being ascertained, as the mechanism of the automaton in the Strand.

That *an animal is a machine* is a proposition neither correctly [perhaps he meant to write 'completely'] true nor wholly false. The distinction I have been discussing shows how far the animal-machine comparison holds, and where it fails. Granted that we know nothing of voluntary motion, of irritability, of the principle of life, of sensation, of animal heat, this ignorance does not compromise our knowledge of the mechanical parts of the animal frame. There *is* mechanism in animals; this mechanism is as properly such as it is in machines made by art; it is intelligible and certain, and is not less so because it often begins or terminates with something that is not mechanical; wherever it is intelligible and certain, it demonstrates intention and contrivance in the works of nature as well as in those of art; and that it is the best demonstration that either can provide.

But there are other cases where, although we cannot exhibit mechanism or even prove that mechanism is employed, we have sufficient evidence of intention and contrivance.

There is what may be called the *chemical* part of our frame. Because of the imperfection of our chemistry, we cannot attain a knowledge of this that is similar in degree or in kind to our knowledge of the mechanical part of our frame. So it does not provide the same species of argument as that mechanism supplies; yet it may provide an argument that is highly satisfactory. The gastric juice that digests the food in the stomachs of animals is of this class. [He talks about the power, versatility and selectiveness of the digestive system, and concludes:] Consider these properties of the digestive organ and of the juice with which it is made to supply itself, and you will confess that it has rightly been called 'the chemical wonder of animal nature'.

Yet we are ignorant of the composition of this fluid and of the mode of its action; by which I mean that we cannot set it alongside the operations of ·human· art, as we can the mechanical part of our frame. I call this the imperfection of our chemistry. The time may come when we can assemble ingredients so as to make a solvent that acts in the way the gastric juice acts; and that may enable us to ascertain the chemical principles on which its efficacy depends, as well as from what part and by what concoction in the human body these principles are generated and derived.

In the meantime, ought the defect of our chemistry hinder us from accepting the inference that a production of nature authorises us—by its place, its properties, its action, its surprising efficacy, its invaluable use—to draw regarding a creative design?

Another most subtle and curious function of animal bodies is secretion. This function is semi-chemical and semi-mechanical, exceedingly important and diversified in its effects but obscure in its process and in its apparatus. The importance of the secretory organs is all too well attested by the diseases that are almost sure to arise from a secretion that is excessive, or deficient, or wrong: a single wrong secretion is enough to make life miserable, and sometimes to destroy it. And the variety matches the importance: from one and the same human blood about twenty different fluids are separated, with utterly different sensible properties; and if we pass to other species of animals, we find among their secretions not only the most various but the most opposite properties—nutritious food and deadly poison, sweet perfumes and foul odours. Most of these, after they are secreted, evidently contribute to the welfare of the animal. (Similar to secretion, if not the same thing, is *assimilation*, by which blood is converted into bone, muscular flesh, nerves, membranes, tendons—things as different as the wood and iron, canvas and cordage, of a ship.)

No operation of art is exactly comparable with all this, perhaps only because all the operations of art are *exceeded* by it. We are not acquainted with any chemical election, any chemical analysis or resolution of a substance into its constituent parts, any mechanical sifting or division, that rises to the level of animal secretion in perfection or variety. Yet the apparatus and process are obscure, not to say absolutely concealed from our inquiries.

In estimating the evidence animal secretions provide of design, think about their variety and their appropriateness to their place and use. They all come from the same blood; they are all drawn off by glands; yet the product is very different, and the difference exactly adapted to the work that is to be done. No account can be given of this without resorting to *appointment*. Why is the saliva insipid, when so many other secretions—urine, tears, and sweat—are salt? Why does the gland within the ear separate a waxy substance that defends that passage, while the gland in the upper angle of the eye secretes a thin brine that washes the eyeball? These are fair questions; and the only answer they can be given brings in intelligence and intention.

My aim in the present chapter has been to teach three things: **(i)** that it is a mistake to suppose that, in reasoning from the appearances of nature, the imperfection [see Glossary] of our knowledge proportionally affects the certainty of our conclusion, for in many cases it does not affect it at all; **(ii)** that the different parts of the animal frame can be classed and distributed according to how exactly we can compare them with works of art; **(iii)** that the mechanical parts of our frame—i.e. those in which this comparison is most complete—although they are probably the coarsest portions of nature's workmanship, are the most proper to be adduced as proofs and examples of design.

8. Mechanisms: bones

I shall discuss certain examples from this class, choosing ones that can be explained without plates, shapes, or technical language, and of those the ones that appear to be the most striking and the best understood.

Bones in general

(1) I challenge any man to produce, in the joints and pivots of the most complicated or most flexible machine ever contrived, a construction more artificial [see Glossary] or more evidently artificial than what is seen in the vertebrae of the human neck. The head was to have the power of **a** bending forward and backward, and of **b** rotating through about 120° of a circle. For these purposes two contrivances are employed. **a** First, the head rests immediately on the uppermost vertebra, and is united to it by a hinge-joint, on which the head plays freely forward and backward. **b** Secondly, between the uppermost vertebra in the neck and the one next below it there is a mechanism resembling a tenon and mortice. The lower of the two has a projection, something like a tooth, which fits into a corresponding socket in the bone above it, forming a pivot on which that upper bone, together with the head it supports, turns freely in a circle. Thus are both motions perfect, without interfering with each other. We see the same contrivance in the mounting of a telescope, for moving it up and down as well as horizontally: **a** a hinge on which the telescope plays, and **b** an axis on which the telescope and the hinge turn around together.

(2) Similar to that in its object, though different in its means, is the mechanism of the forearm. For this, two motions are wanted: **a** a motion at the elbow backward and forward, and **b** a rotatory motion by which the palm of the hand may be turned upward. How is this managed? The forearm consists of two bones lying alongside each other but touching only towards the ends. **a** One of these bones is joined to the upper part of the arm at the elbow; **b** the other is joined to the hand at the wrist. The first, by means of a hinge joint at the elbow, swings backward and forward, carrying with it the whole forearm. The other bone, to which the hand is attached, rolls on the first bone by the help of a groove or hollow near each end of one bone, to which is fitted a corresponding prominence in the other. If both bones had been joined to the upper arm at the elbow, or both to the hand at the wrist, the thing could not have been done. The first was to be at liberty at one end, and the second at the other, so that the two actions could be performed together. [Paley elaborates this account at considerable length.]

(3) The spine is a chain of joints of very wonderful construction; various difficult and almost inconsistent offices were to be performed by the same instrument. It was to be **a** firm, to support the erect position of the body, and **b** flexible, to allow the trunk to bend in all degrees of curvature. It was further also **c** to become a pipe or conduit for the safe conveyance from the brain of the spinal marrow—

> the most important fluid of the animal frame, on which all voluntary motion depends, a substance needed for action, if not for life, but also so delicate and tender that any unusual pressure on it or obstruction of its course is followed by paralysis or death.

As well as providing the main trunk for the passage of the medullary substance from the brain, the spine had to **d** give out along the way small pipes which being afterwards indefinitely subdivided could (under the name of 'nerves') distribute this exquisite supply to every part of the body. The same spine was also to **e** provide a fulcrum (or more properly speaking a series of these) for the insertion of the muscles that are spread over the trunk of the body.

Commission a workman to make a mechanism that will achieve all these purposes, and he will find it hard to comply until he is told how the same thing is effected in the animal frame.

For the spine to be **a** firm yet **b** flexible, it is composed of a great number of bones (in humans twenty-four) joined to one another and compacted by broad bases. The breadth of the bases on which the parts separately rest and the closeness of the junction give the chain its firmness and stability; the number of parts, and consequent frequency of joints, provide its flexibility. In order to provide **c** a passage for the descent of the medullary substance, each bone is bored through in such a way that the hole in any one bone lines up with the holes in the two bones contiguous to it; so that the perforated pieces form an entire, close, uninterrupted channel; at least while the spine is upright and at rest. But there had also to be some way to prevent the vertebrae from shifting on one another, so as to break the line of the canal when the body moves or twists; and to prevent the joints from gaping externally when the body is bent forward. [Paley describes the 'mechanical' solution to this problem, involving the interlocking of the vertebrae and the placing of 'springy' cartilages between them.] **d** For the medullary canal to send out a supply of nerves to different parts of the body, notches are made in the upper and lower edge of every vertebra, two on each edge, equidistant on each side from the middle line of the back. These notches, exactly fitting, form small holes through which the nerves issue out in pairs, to send their branches to every part of the body. As for **e** the insertion of the bases of the muscles, a shape specifically suited to this design and unnecessary for the other purposes is given to the constituent bones.

[Paley then describes how the vertebrae 'lock in with and overwrap one another' so as to prevent any 'from being pushed out of its place', and notes that we can see, understand, and admire this arrangement in the spine of a hare after its meat has been eaten. He concludes:] The general result is that •the motions of the human body needed for everyday life are performed with safety, and that •it seldom happens that an acrobat's movements distort his spine.

The structure of the spine is not in general different in different animals. In the serpent tribe it *is* considerably varied, but with a strict reference to the convenience of the animal. Whereas quadrupeds have 30 to 40 vertebrae, serpents have nearly 150; whereas in men and quadrupeds the surfaces of the bones are flat, and these flat surfaces laid one against the other and tightly bound by sinews, in serpents the bones play one within another like a ball and socket, so that they have a free motion on one another in every direction. In short, in men and quadrupeds firmness is more consulted; in serpents, pliancy.

(4) The reciprocal enlargement and contraction of the chest to allow for the play of the lungs depends on a simple yet beautiful mechanical contrivance involving the structure of the bones that enclose it. The ribs articulated to the back-bone, in their natural position, slope from the place of articulation downwards. The result is that **a** when they come to move, whatever pulls the ribs upwards necessarily also draws them out; and that **b** while the ribs are brought to a right angle with the spine behind, the sternum—the part of the chest they are attached to in front—is thrust forward. So the simple action of the elevating muscles does the business. If **a** the ribs had been articulated with the vertebrae at right angles, the cavity of the thorax could never have been further enlarged by a change of their position; and if **b** each rib had been a rigid bone rigidly fixed at both ends, the whole chest would have been immovable. The thorax, says Schelhammer, forms a kind of bellows such as never has been and probably never will be made by any artificer.

(5) The patella or kneecap is a curious little bone, different in form and office from any other bone in the body. [He describes its shape and situation, and its 'offices', mainly protecting the knee-joint from injury. He adds:] It appears to be supplemental to the frame, not quite necessary but very convenient. [He then writes about the shoulder-blade, commenting on its singular lack of connection with any other bones ('in strictness, it forms no part of the skeleton'), but not offering it as evidence of contrivance.]

Joints

(1) The above are a few examples of bones made remarkable by their configuration; but almost all the bones have joints, in which we see both contrivance and contriving wisdom even more clearly than in the shape of the bones themselves. There are two sorts of joint: **a** the hinge and **b** the ball and socket; and one or the other prevails, depending on what motion is wanted. For example, the **b** ball and socket joint is not required at the knee, because the leg needs only a motion backward and forward in the same plane, for which **a** a hinge joint is sufficient. A **b** ball and socket joint is needed at the hip, to provide not only for walking forwards but also for spreading the legs. Think what would have been the inconvenience if the ball and socket joint had been at the knee, and the hinge joint at the hip! The disadvantage would not have been less if the joints at the hip and the knee had both been of the ball and socket type, or both been hinges: yet why, apart from utility and a Creator who consulted that utility, should the thigh bone be **b** rounded at one end and **a** channelled at the other?

The hinge joint is not formed by a bolt passing through the two parts of the hinge and thus keeping them in their places; but by a different expedient. A tough, parchment-like membrane, arising from the receiving bones and inserted all around the received bones a little below their heads, encloses the joint on every side. This membrane holds the ends of the bones together, keeping the corresponding convexities and concavities in close application to each other.

The ball and socket joint also has a membrane like that; and for some important joints there is an additional security—a short, strong, flexible ligament inserted by one end into the head of the ball, by the other into the bottom of the cup. This keeps the two parts of the joint so firmly in their place that none of the motions the limb naturally performs can pull them apart. This ligament, which is so flexible that it does not hinder the suppleness of the joint, is too strong to be ruptured and too well protected by bone to be cut. I don't know if there is any example of mechanism more unambiguous, or more free from objection, than this ligament. It is utterly mechanical, subservient to the safety of the joint, yet incapable of being *generated* by the joint's action. I would especially ask you to attend to this provision, as it is found in the head of the thigh-bone—to its strength, its structure, and its use. It is an instance on which I lay my hand. For various reasons we multiply examples; but for the purpose of strict argument one clear instance is sufficient; and not only sufficient but capable perhaps of generating a firmer assurance than can arise from a divided attention.

Another no less important hinge joint is the ankle. This joint is strengthened by two remarkable prolongations of the bones of the leg, forming the protuberances that we call the inner and outer ankle. Between both the ankle is locked in its position. I know no explanation for this structure except its utility. Why should the tibia's lower end be double, with one part going lower than the other, and similarly for the fibula's, except to protect the joint on both sides?

The joint at the shoulder compared with the joint at the hip, though both are ball and socket joints, shows a difference in their form and proportions that is well suited to the relevant limbs' different offices. The socket at the shoulder is much shallower and flatter than the one at the hip, and unlike the other is partly made of cartilage set around the rim. This fits with the duties assigned to each part: the arm is principally an instrument of motion; whereas the lower limb has to support the body as well as being the means of its locomotion, so for it firmness was to be consulted as well as action.

We every moment experience the suppleness and pliability of the joints. As for the firmness of animal articulation, consider the fact that despite the contortions and wrenches to which the limbs of animals are continually subject, there are millions of animal joints in complete repair and use for every one that is dislocated.

(2) The nerves, blood-vessels and tendons that are necessary for the animal's life or for the motion of the limbs must travel over the movable joints, and must be protected from compression, attrition, or laceration through sudden motions and abrupt changes of curvature. This is done with peculiar care by a provision in the shape of the bones themselves. [He describes how this is done at the elbow, at the knee, and at the shoulder, with a colourful summing up of the knee situation:] The great vessels and nerves that go to the leg pass along a defile between rocks.

(3) The ends of the bones that work against each other in a joint are tipped with gristle; in the ball and socket joint the cup is lined and the ball capped with it. The smooth surface and the elastic and unfriable nature of cartilage make it the most proper of all substances for the place and purpose. I would have pointed this out earlier, if it had not been alleged that cartilage is really only imperfect bone, kept soft and imperfect by the continual motion and rubbing of the surfaces; in which case it is not **a designed advantage** but merely **an unavoidable effect**. I am not convinced that this is correct: the surmounting of the ends of the bones with gristle looks to me more like •a plating with a different metal than like •the same metal kept in a different state by the action to which it is exposed. Either way, we have a great *particular* benefit; if it arises from a *general* constitution, it is not quite what my argument requires; and I have thought it fair to state the question that arises about it, lest I should seem to overrate its value.

(4) [A discussion of the 'loose cartilages' in some joints, especially the knee, whose 'slipping and sliding' facilitates the working of the joint. Paley compares them with the 'loose rings' that mechanics put 'between the parts of crook-hinges of large gates'.]

(5) We have now done with the configuration of the joints; but there is also in them all a regular supply of a mucilage, more emollient and slippery than oil itself, which constantly softens and lubricates the parts that rub on each other and thereby enormously reduces the amount of wear. For the continual secretion of this important liniment, and for feeding the cavities of the joint with it, glands are fixed near to each joint. A recent improvement in so-called 'friction wheels'—a mechanism in which oil is regularly dropped into a box that encloses the axis, the nave, and ball-bearings on which the nave revolves—has some resemblance to the contrivance in the animal joint; but the joint is superior, because in it the oil is not only dropped but made.

In considering the joints, there is perhaps nothing that should move our gratitude more than *how well they wear*. A limb swings on its hinge or plays in its socket hundreds of times an hour, for sixty years, without losing any of its agility. I attribute this durability in part to •the provision that is made for preventing wear and tear by the polish of the cartilaginous surfaces and by the healing lubrication of the mucilage; and in part to •that astonishing property of animal constitutions, *assimilation*, by which throughout the body substance is restored and waste repaired.

The union of bones, even where no motion is intended or wanted, carries marks of mechanism and of mechanical wisdom. The teeth, especially the front teeth, are one bone fixed in another like a peg driven into a board. The sutures of the skull are like the edges of two saws pushed together so that the teeth of one enter the intervals of the other. We have sometimes one bone lapping over another and planed down at the edges; sometimes the thin lamella of one bone received into a narrow furrow of another. All these seem to reveal the same design, namely firmness of union without clumsiness in the seam.

9. Mechanisms: muscles

Muscles, with their tendons, are the instruments by which animal motion is performed. I shall point out instances in which, and properties with respect to which, the disposition of these muscles is as strictly mechanical as that of the wires and strings of a puppet.

(1) Throughout the animal body there is an exact relation between the joint and the muscles that move it; whatever motion the joint's mechanical construction enables it to perform can be produced by the annexed muscles by virtue of their position. For example, when (as at the knee and elbow) there is a hinge joint, capable of motion only in the same plane, the muscular tendons are parallel to the bone, so that by the contraction or relaxation of the muscles they produce that motion and no other. If these joints were capable of a freer motion, there are no muscles to produce it. Whereas at the shoulder and the hip, where the ball and socket joint allows of a rotatory or sweeping motion, tendons are so placed as to produce the motion of which the joint admits. [He goes into some detail about the hip, then moves on to the head and hands, noting a special feature of the muscles relating to the head, namely that they are] capable of steadying the globe as well as of moving it. The head of a new-born infant is often obliged to be held up; after death, the head drops and rolls in every direction.

As another example of the conformity of use between the bones and the muscles, it has been observed that the processes of the different vertebrae are exactly proportioned to the amount of motion that the other bones allow of and that the relevant muscles are capable of producing.

(2) A muscle acts only by contraction; its force is exerted in no other way. When the exertion ceases, the muscle returns by relaxation to its former state, but without energy. This is the nature of the muscular fibre. Because of this, a limb can be moved with force in opposite directions only if it has opposite or antagonist muscles, flexors and extensors corresponding to each other. [He describes these in some detail for the elbow, then continues:] The same thing obtains for every movable part of the body. Every muscle is provided with an adversary. They act, like two sawyers in a pit, by an opposite pull; and nothing can more strongly indicate design and purpose than their being thus placed in this way.

(3) Another property of the muscles that could only be the result of care is their being almost universally so disposed as not to interfere with one another's action. (The only example of such interference that I know of is the fact that we cannot easily swallow while we gape.) There are at least 446 muscles in the human body, known and named, situated in layers over one another, crossing one another, sometimes embedded in one another, sometimes perforating one another; yet each has its liberty, its full play; and this can only have come from meditation and forethought.

(4) It is often the case that a muscle's action is needed at a place where it would be inconvenient for the muscle to be situated. In such a case the body of the muscle is placed at a distance and made to communicate with the point of action by slender strings or wires. If the muscles that move the fingers had been placed in the palm or back of the hand, they would have swelled that part to an awkward and clumsy thickness. So they are disposed in the arm, even up to the elbow, and act by long tendons, strapped down at the wrist and passing under the ligaments to the joints of the fingers that they are severally to move. Similarly with the muscles that move the toes, and the muscle that draws the eyelid over the eye.

(5) It appears to be a fixed law that *the contraction of a muscle shall be towards its centre*. So each muscle has to have a shape and position that will produce the required motion, in conformity with this law. So we find muscles with a multiplicity of forms and attitudes; sometimes with double tendons, sometimes with treble, sometimes with none; sometimes one tendon to several muscles, at other times one muscle to several tendons. The shape of the organ is capable of enormous variety, while the unchanging law and line of its contraction is simple. The muscular system is in this respect like our works of art [see Glossary]. An artist does not alter the basic nature of his materials, or their laws of action. He takes these as he finds them. His skill and ingenuity are employed in turning them to his account, by giving to the parts of his machine a form and relation in which these properties can produce the intended effects.

(6) We can never say it too often:

- •How many things must go right for us to be at ease for an hour!
- •How many more things must go right for us to be vigorous and active!

Yet vigour and activity are preserved in nearly all human bodies, although they depend on so many instruments of motion, and although the defect of a single pair out of the 446 muscles that are employed may bring grievous inconvenience. [He tells of a man who, because of the failure of 'two little muscles', could raise his eyelids only by hand.] Those who enjoy the perfect use of their organs are in general very unaware of the comprehensiveness of the blessing, the variety of their obligation. They perceive a result, but hardly think of the multitude of concurrences and rectitudes that produce it.

The speed and precision of muscular motion

(1) The variety, quickness and precision that muscular motion is capable of are nowhere more remarkable than in the tongue. Watch the agility of your tongue—the wonderful speed and exactness with which it changes its position. Each syllable of articulated sound requires a specific action of the tongue and of the parts adjacent to it. Every letter and word requires a disposition and configuration of the mouth that is not only special to that sound but, if carefully attended to, perceptible to the sight; a fact that has enabled some people to teach the deaf to speak and to understand what is said by others. After someone's habit of speaking has been formed, one and only one position of the parts will yield a given articulate sound correctly. How instantaneously are these positions adopted and then dismissed! How numerous are the permutations, how various yet how infallible! I believe that the •anatomy of the tongue corresponds with these observations on its •activity. Its muscles are so numerous and so interwoven that they cannot be traced by the most careful dissection; yet neither the number, nor the complexity, nor the apparent entanglement of its fibres in any way impede its motion or make the success of its efforts uncertain. This is a great perfection of the organ.

A digression on the mouth

Allow me to step a little out of my way to consider some of other properties of the parts of the mouth. An eminent physiologist has said that whenever nature tries to work two or more purposes by one instrument, it does them imperfectly. Is this true of the tongue, regarded as an instrument of speech, of taste, and of swallowing? It is so far from true that 99.9% of persons, by the instrumentality of this one organ, talk, taste and swallow very well. In fact, the constant warmth and moisture of the tongue, the thinness of the skin and the papillae on its surface qualify this organ for its office of tasting, as much as its inextricable multiplicity of fibres qualify it for the rapid movements needed for speech.

The cavity of the mouth involves more distinct uses, and contains parts performing more distinct offices, than I think can be found lying so near to one another in any other part of the body, namely:

- teeth of different shapes, first for cutting, secondly for grinding;
- muscles artfully disposed for carrying on the compound motion of the lower jaw, half lateral and half vertical, by which the mill is worked;
- fountains of saliva, springing up in different parts of the mouth for moistening the food while it is being chewed;
- glands to feed the fountains;
- a very special kind of muscular constriction at the back of the cavity, for guiding the prepared food into its passage towards the stomach and in many cases for carrying it along that passage.

We may imagine this last to be done simply by the weight of the food itself, but in truth it is not so.

In the meantime, within the same cavity, another business is going on—that of breathing and speech. In addition to the apparatus described above, we have

- a passage from this cavity to the lungs, to admit air and nothing else;
- muscles, some in the larynx and countless others in the tongue, to modulate that air in its passage with more variety, range and precision than any other musical instrument is capable of;

and, the crowning achievement,

- a specific contrivance for dividing the pneumatic part from the mechanical—the breathing from the eating—and preventing one set of actions interfering with the other.

Where various functions are united, the problem is to guard against the drawbacks of too much complexity. I know of no humanly constructed apparatus where such multifarious uses are so aptly combined, or where the structure (compared with the uses) is so simple, as in the human mouth. The mouth is one machine, with its parts neither crowded nor confused, and each unembarrassed by the rest; each at least sufficiently at liberty for the end to be attained. If we cannot eat while we sing, we can eat at one moment and sing the next, with breathing proceeding freely all the while.

However, the mouth alone could not perform the double office of sucking and breathing. So another route is opened for the air, namely through the nose, which lets the breath pass backward and forward while the lips have to be shut close on the body from which the nutriment is drawn. The nose would have been necessary even if it were not the organ of smelling. Making it the seat of a *sense* was wisely adding a new use to a part that was already needed.

Returning to the speed and precision of muscles

But to return to the proper subject of the present section, the speed and precision of muscular motion.

(1) These qualities are very visible in the performance of many kinds of instrumental music, where the movements of the musician's hand are exceedingly rapid and are exactly measured even when they are very minute. They display, on the part of the muscles, an obedience of action that is wonderful for its speed and its correctness.

Or observe your own hand while you are writing: the number of muscles that are brought to bear on the pen; how the operation of several tendons is involved in every stroke, yet five hundred such strokes are drawn in a minute. When we look at he finished product, how faithful the muscles have been to their duty! how true to the order inculcated by endeavour or habit! Bear in mind that while a man's handwriting is the same, an exactitude of order is preserved, whether he writes well or badly. The examples of music and writing show not only the speed and precision of muscular action, but also its docility [i.e. its capacity to be trained].

(2) Sphincter or circular muscles appear to me admirable pieces of mechanism, because their semi-voluntary character is exactly what suits the wants and functions of the animal. [He explains, not very clearly, what this character consists in: much of the time we can choose whether to keep a sphincter closed or let it open, but when the pressure is great enough we cannot keep it closed.]

(3) Many of our most important actions are achieved by the combined help of different muscles. Sometimes the number of co-operating muscles is very great. Dr Nieuentyt in the *Leipsic Transactions* reckons that a hundred muscles are employed every time we breathe; yet we breathe in and out without reflecting on what a work is thereby performed—how many instruments contribute to this. Breathing with ease is a blessing of every moment, yet it is the one we are least conscious of. A man with asthma is the only one who knows how to estimate it.

(4) Mr Home has observed that the most important and the most delicate actions are performed in the body by the smallest muscles. The examples he gives are the muscles that have been discovered in the iris of the eye and in the drum of the ear. The thinness of these muscles is astonishing. They are microscopic hairs, and must be magnified to be visible; yet are they real, effective muscles whose health and action are required for the grandest and most precious of our faculties, sight and hearing.

(5) The muscles act in the limbs with what is called a "mechanical disadvantage'. [Paley explains this as what you have in raising •a light weight a good distance along a lever by means of •a heavy weight very close to the fulcrum.] The muscle at the shoulder is of this kind. It would indeed be a disadvantage if the aim were to spare the force of muscular contraction [i.e. to avoid the analogue of the heavy weight]. But that is usually not what is wanted. Mechanism always aims either at **a** moving a great weight slowly through a small space or **b** moving a light weight rapidly through a considerable sweep. For **a** the former of these a different arrangement of the muscles might be better than the actual one, but for **b** the second purpose the actual structure is just right. Now it so happens that **b** the second and not the **a** first is what the occasions of animal life principally call for. On some extraordinary occasions a man may wish he could **a** raise from the ground a much heavier load than he can lift at present; but it is much more important for him to be able to **b** raise his hand to his head quickly, this being something he wants and uses every hour or minute. In general, the vivacity of animals' motions would be ill exchanged for greater force under a clumsier structure.

I have discussed muscles in general, then certain species of muscles; but there are also single muscles that bear marks of mechanical contrivance. Out of many instances of this kind I select the following.

Three individual muscles

(1) [In this paragraph Paley describes in some detail the muscular structure that produces, 'in a most wonderful and elegant manner', the movement of the lower jaw.]

(2) What contrivance can be more mechanical than a slit in one tendon to let another tendon pass through it? This structure is found in the tendons that move the toes and fingers. The long tendon in the foot, which bends the first joint of the toe, passes through the short tendon which bends the second joint; and this course allows to the sinew more liberty and a more free action than it could have exerted otherwise. I don't think that in a silk or cotton mill—in the belts, straps, ropes by which motion is communicated from one part of the machine to another—there is anything more artificial, or more evidently so, than this perforation.

(3) The tendons that pass from the leg to the foot are bound down by a ligament at the ankle. The foot is placed at a considerable angle with the leg. Obviously, flexible strings passing along the interior of the angle would, if left to themselves, pull away from it. The obvious preventive is to tie them down, and that is what is done in fact. Just above the instep the anatomist finds a strong ligament *under* which the tendons pass to the foot. The effect of the ligament as a bandage can be made evident to the senses; for if it is cut, the tendons move upwards. The simplicity yet clearness of this contrivance—its exact resemblance to established resources of ·human· art—make it one of the most convincing signs of *design* that we know.

The present example precisely contradicts the opinion that the parts of animals may have all been formed by *endeavour*, perpetuated and imperceptibly working its effect through an incalculable series of generations. We have here no endeavour but the reverse of it—a constant resistance and reluctance, the endeavour all going the other way. The pressure of the ligament constrains the tendons; the tendons react to the pressure of the ligament. The ligament could not possibly have been generated by the exercise of the tendon, because the force of the tendon perpendicularly resists the fibre that confines it and is constantly endeavouring not to
•form the threads of which the ligament is composed but to
•rupture and displace them.

Two final remarks about muscles

Bishop Wilkins has observed from Galen that there are at least ten factors to be attended to in each muscle:

- •its proper shape,
- •its just magnitude,
- •its fulcrum,
- •its point of action, supposing the shape to be fixed,
- •its collocation with respect to its upper and lower ends,
- •the place,
- •the position of the whole muscle,
- •the introduction into it of nerves,
- •arteries,
- •veins.

How can things needing so many adjustments be made, and when they are made how can they be put together, without intelligence?

I have sometimes wondered why we are not struck with mechanism in animal bodies as readily and as strongly as we are struck with it at first sight in a watch or a mill. Perhaps it is partly because animal bodies are largely composed of soft, flabby substances such as muscles and membranes; whereas we have been accustomed to detecting mechanism in sharp lines, in the configuration of hard materials, in the moulding, chiselling, and filing into shapes of materials such as metals or wood. In fact, mechanism can be displayed in the soft kind of substance as well as in the hard; it is sufficiently evident that there can be no proper reason for any distinction of the sort.

10. Mechanisms: vessels

(1) The circulation of the blood through the bodies of men and quadrupeds, and the apparatus by which it is carried on, compose a system that is perhaps the best understood part of the animal frame. The lymphatic system and the nervous system may be more subtle and intricate; indeed, in their structure they *may* be even more artificial than the blood system; but we do not know so much about them.

One grand purpose of the circulation of the blood is the distribution of the nourishment that the body receives by one aperture to every part, every extremity, every nook and corner, of it. What enters at the mouth finds its way to the fingers' ends. How to repair the waste of a complicated machine while also giving some substance access to every part of it—a difficult mechanical problem!

This system involves two factors: •the disposition of the blood-vessels, i.e. the laying of the pipes; and •the construction of the engine at the centre—namely, the heart—for driving the blood through them.

The lay-out of the pipes

The disposition of the blood-vessels for supplying blood to the body is like that of the water-pipes in a city—large trunks branching off into smaller pipes (and these again by still narrower tubes) in every direction, towards every part where the conveyed fluid can be wanted. But another thing that is necessary for the blood but not wanted for the water is carrying it back again to its source. For this office a reversed system of vessels is prepared. These unite at their extremities with the extremities of the vessels of first system; they collect the divided and subdivided streamlets, first by capillary ramifications into larger branches and then by these branches into trunks; and in this way the second system returns the blood (almost exactly inverting the order in which it went out) to the fountain from which its motion proceeded. All this is evident mechanism.

So the body contains two systems of blood-vessels, arteries and veins, between which there are two differences, suited to the functions the systems have to perform. **a** Because the blood in going out passes from wider into narrower tubes, and in coming back from narrower into wider, it is evident that the pressure on the sides of the blood-vessel will be much greater in one case than the other. Accordingly, the arteries that carry out the blood are formed of much tougher coats than the veins that bring it back. **b** Because of the greater force with which the blood is urged along the arteries, a wound or rupture in them would be more dangerous than one in the veins; so these vessels are defended from injury not only by their texture but by every advantage of *situation* that can be given to them. They are buried in sinuses, or they creep along grooves made for them in the bones. Sometimes they proceed in channels, protected by stout parapets on each side, notably in the bones of the fingers. At other times the arteries pass in canals wrought in the very middle of the substance of the bone—for example in the lower jaw, where there would otherwise be danger of compression by sudden curvature. All this care is wonderful, yet not more than what the importance of the case required. It has been often said that for those who venture their lives in a ship there is only an inch-board between them and death; but in the body itself, especially in **a** the arterial system, there is in many parts only a membrane, a skin, a thread. That is why this system lies deep under the integuments, whereas **b** the veins, in which the harm from injury is much less, generally lie above the arteries, come nearer to the surface, are more exposed.

The arterial system, with its trunk and branches and small twigs, may be imagined to *grow* from the heart, like a plant from its root; but the returning system of veins could not be formed in this manner. The arteries might go on shooting out from their extremities, lengthening and •dividing indefinitely; but an inverted system, continually •uniting its streams, could not arise from the same process.

The engine at the centre

The next thing to be considered is the engine that works this machinery, namely the heart. For my purpose it is unnecessary to know what drives the heart; all that matters is that it is *something* that can produce alternating contraction and relaxation in a living muscular fibre. This is the power we have to work with, and the inquiry concerns how this power is applied in the instance before us. In the central part of the body there is a hollow muscle, invested with spiral fibres running in both directions, the layers intersecting one another. By the contraction of these fibres the sides of the muscular cavities are squeezed together so as to force out from them any fluid they contain; by the relaxation of the same fibres the cavities are dilated and thus prepared to admit every fluid that may be poured into them. Into these cavities are inserted the great trunks, both of the arteries that carry out the blood and of the veins that bring it back. That is, by each contraction a portion of blood is forced by a syringe into the arteries: and at each dilatation an equal portion is received from the veins. [He exclaims about the sheer amount of blood that passes through the human heart in an hour, with the account rising to a crescendo in describing what happens in the heart of a whale.]

The foregoing account is true but imperfect [see Glossary]. The heart also performs another office, which is of equal curiosity and importance. It was necessary that the blood should be successively brought into contact, or contiguity, or proximity with the air. [He says that it isn't certain *why* there is this need, though probably blood has a role in the transfer of impurities between the 'pure and vital' air we breathe in and the 'foul and noxious' air we breathe out. Uncertainty about why the blood needs to be 'visited by continual accesses of air' does not matter here, because] it is sufficient to know that in the constitution of most animals air must be introduced somehow into a near communication with the blood. The lungs of animals are constructed for this purpose. They consist of blood-vessels and air-vessels lying close to each other; with each branch of the windpipe lying between a branch of the vein and a branch of the artery. When the blood is received by the heart from the veins of the body, and *before* it is sent out again into its arteries, it is forced by the contraction of the heart along a supplementary artery to the lungs. Then, after it has been concocted and prepared by the action (whatever it may be) of the lungs, it is brought back to the heart by a large vein and from there is distributed anew into the system. This gives the heart a double office. The pulmonary circulation is a system within a system, and one action of the heart is the origin of both.

Four cavities are needed for this complicated function, and four are accordingly provided:

- two ‘ventricles’, one sending blood into the lungs, the other sending it into the rest of the body after it has returned from the lungs; and
- two ‘auricles’, one receiving blood immediately from the body, the other receiving it after its circulation through the lungs.

So there are two forcing cavities and two receiving cavities. The receiving cavities communicate with the forcing cavities and, by their contraction, unload the received blood into them; and the forcing cavities by *their* contraction compel the same blood into the mouths of the arteries.

‘The wisdom of the Creator’, says Hamburgher, ‘is in nothing seen more gloriously than in the heart.’ And how well it does its job! An anatomist who understood the structure of the heart might predict that it would work; but I think he would expect, given the complexity of its mechanism and the delicacy of many of its parts, that it would always be liable to breakdown, or that it would soon wear out. Yet this wonderful machine keeps going, night and day, for 80 years together at the rate of 100,000 strokes every twenty-four hours, having at every stroke to overcome a great resistance—doing this without disorder and without weariness!

A valve is placed in the communication between each auricle and its ventricle, so that when the ventricle contracts, none of the blood goes back into the auricle instead of entering the mouth of the artery. And a valve is fixed at the mouth of each of the great arteries that take the blood from the heart, leaving the passage free so long as the blood moves forward, and closing it whenever, because of the relaxation of the ventricle, the blood would otherwise flow back. [Paley goes into a great deal of detail about how these valves are structured and how they operate, and he exclaims ‘Can anyone doubt of contrivance here, or is it possible to shut our eyes against the proof of it?’]

We cannot consider without gratitude how happy it is that our vital motions are involuntary. We would have enough to do if we had to keep our hearts beating and our stomachs at work!

It might be expected that an organ of such central and primary importance as the heart is would be defended by a case. Indeed, a membranous bag made of tough materials is provided for it, loosely holding the heart within its cavity, guarding its substance without confining its motion, and containing just enough water to keep the surface of the heart supple and moist. How could such a loose covering be generated by the action of the heart? Does not this enclosing of the heart in a sack show the *care* that has been taken for its preservation?

One use of the circulation of the blood (probably among others) is to distribute nourishment throughout the body. How minute and multiplied the ramifications of the blood-vessels are for that purpose, and how thickly spread, at least over the body’s surface, is shown by the fact that we cannot prick a pin into the flesh without finding a blood-vessel. Similarly with the body’s interior. Blood-vessels run along the surface of membranes, pervade the substance of muscles, penetrate the bones. Every tooth, even, has a small hole in the root, allowing an artery to feed the bone and a vein to bring back the spare blood from it; and these two, with the addition of an accompanying nerve, constitute a thread only a little thicker than a horse-hair.

The intestinal system

This introduces another large topic, namely the way the aliment gets into the blood. This is a subject distinct from the preceding, and brings us to the consideration of another entire system of vessels.

(2) First, the food descends by a wide passage into the intestines, undergoing two great preparations on its way, one in the mouth by chewing and moisture, the other by digestion in the stomach itself. I say nothing about the second, because it is •chemistry and I want to display •mechanism. The shape and position of the human stomach are just right for detaining the food long enough for the action of its digestive juice. As for the bile or pancreatic juice, setting aside its chemistry I offer this about its mechanism: from the glands in which these secretions are developed, pipes run to the first of the intestines, where the product of each gland is mixed with the aliment almost as soon as it passes the stomach.

Secondly, we now have the aliment in the intestines, converted into pulp; and though recently consisting of ten different foods it is reduced to a nearly uniform substance, and to a state fitted for yielding its essence, which is called 'chyle' (which is more like milk than anything else). For straining off this fluid from the digested aliment in the course of its long progress through the body, myriads of pipes as small as hairs open into the cavity of every part of the intestines. These tubes, called 'lacteals', soon unite into larger branches; and the pipes formed by this union terminate in glands, from which other larger pipes carry the chyle from all parts into a common reservoir or receptacle that is big enough to hold about two tablespoons full. From this a duct runs up the back part of the chest, then creeping along the gullet till it reach the neck. Here it discharges itself into a large vein, which soon conveys the chyle—now flowing along with the old blood—to the heart. This whole route can be exhibited to the eye ·when a corpse is dissected·; there is no need for imagination or conjecture. This structure, collectively considered, is obviously dedicated to a necessary purpose; and some aspects of it show the *perfection* of its contrivance.

a In human beings the intestine is six times as long as the body. This prolixity of gut does not seem necessary for the transfer of the material; but the length of the canal is obviously useful because it allows chyle that escapes the lacteals of one part of the guts to be taken up by others further on. **b** The intestine's motion is peristaltic: contractions following one another like waves on the surface of a fluid, quite like an earthworm crawling along the ground. This is brought about by the joint action of longitudinal fibres and of a great number of semicircular ones. This remarkable action pushes forward the grosser part of the aliment, while the more finely divided chyle is gently squeezed into the narrow orifices of the lacteal veins. **c** These lacteals, or at least their mouths, needed to be as narrow as possible, so as to prevent entry into the blood of any particle big enough to create a blockage in a small artery and thus obstruct the circulation; and accordingly their orifices opening into the intestines are too small to be discernible even by the best microscope. Also, because the lacteals are so thin, there have to be incalculably many of them. **d** The chyle enters the blood at an odd place, but perhaps the most best place possible, namely at a large vein in the neck, from which it can speedily to bring the mixture to the heart. This seems to be important; for if the chyle entered the blood at an artery, or at a distant vein, the mixture of old blood and recent chyle would perform a considerable part of the circulation before getting the churning in the lungs that is probably required for the mixture to be perfect. Who could have dreamed that all nourishment is delivered to the body through a communication between the cavity of the intestines and the left great vein of the neck?

A chemical interlude: digestion

I *postponed* discussion of digestion so as not to interrupt my tracing of the passage of the food to the blood; but in treating of the alimentary system I cannot *omit* such a principal part of the system.

The immediate agent by which food is changed in our stomachs is the *gastric juice*. I shall take my account of it from the numerous careful and varied experiments of the Abbé Spallanzani:

(a) It does not merely dilute; it dissolves. A quarter of an ounce of beef had scarcely touched the stomach of a crow when the dissolution began.

(b) It does not have the nature of saliva, or of bile; it is distinct from both. Experiments out of the body show that neither of these secretions acts on alimentary substances in the way the gastric juice acts.

(c) Digestion is not putrefaction; for the digesting fluid stubbornly resists putrefaction—indeed it not only checks its further progress but restores putrid substances.

(d) It is not a process of fermentation; for the dissolving begins at the surface and proceeds towards the centre, contrary to the order in which fermentation acts and spreads.

(e) It is not the digestion of *heat*; for, the cold maw of a cod or sturgeon will dissolve the shells of crabs or lobsters, which are harder than the sides of the stomach containing them.

In short, animal digestion seems to be a power and a process completely *sui generis*, distinct from every other chemical process we know about. And the most wonderful thing about it is its suitability to the particular economy of each animal. [Then a lot of detail about how the differences in •the food of birds of prey, sparrows, poultry, sheep and cows are matched with differences in •the selective powers of their gastric juices and in •the mechanical arrangements for bringing the juices to bear on the food. In these cases, Paley says, what is needed—and provided—is 'a combination of mechanism and chemistry'.] But to return to our hydraulics.

Back to mechanism: bile and saliva

(3) The gall bladder is a very remarkable contrivance. It is the reservoir of a canal. It does not form the channel giving direct communication between the liver and the intestine, which is provided by another passage. The gall bladder lies adjacent to this channel, joining it by a duct of its own, which enables it to increase, as occasions may require, the flow of bile into the duodenum. In its natural situation, it touches the exterior surface of the stomach, and consequently is compressed when the stomach is distended; this has the effect that when the repletion of the stomach by food is about to create a need for an extraordinary quantity of bile, this quantity is forced out from the gall bladder and sent into the duodenum.

The entrance of the gall duct into the duodenum provides another observation. Whenever •smaller tubes are inserted into larger ones, or •tubes are inserted into vessels and cavities, with the receiving tubes or cavities being subject to muscular constriction, we always find a contrivance to prevent regurgitation. In some cases valves are used; with the gall duct (and also the ureters) something different is resorted to. The gall duct enters the duodenum obliquely; after it has pierced the first coat, it runs for an inch or two between the coats before opening into the cavity of the intestine. This structure mechanically resists regurgitation; for any force acting in such a direction as to urge the fluid back into the orifice of the gall duct must at the same time stretch the coats of the duodenum and thereby compress the part of the duct that lies between them.

(4) The pipe conveying the saliva from where it is made to the place where it is wanted deserves to be counted among the most intelligible pieces of mechanism that we know about. Although the saliva is used in the mouth, much of it is produced on the outside of the cheek by a gland lying between the ear and the angle of the lower jaw. Running from that gland there is a pipe, about the thickness of a wheat straw and about two inches in length; after riding over the masseter muscle, this bores for itself a hole through the very middle of the cheek, through which it discharges its fluid very copiously into the mouth.

The windpipe

(5) Another exquisite structure is seen in the larynx. Unlike the preceding four, it does not concern the conveyance of fluids, but it is like them in being one of the vessels of the body. We all know that two pipes go down the throat—one to the stomach for food, the other to the lungs for breathing and speaking—each with an opening at the bottom of the mouth. With these being so close to one another, the problem was to prevent food, especially liquids, from entering the windpipe, i.e. the road to the lungs. When this error *does* happen, it instantly produces convulsive throes. The problem is elegantly solved as follows. The gullet (the passage for food) opens into the mouth like the cone of a funnel, the capacity of which does indeed constitute the bottom of the mouth. Into the side of this funnel, at the lowest part, the windpipe enters through a chink or slit, with a lid snugly fitted to the opening. The solids or liquids that we swallow pass over this lid as they descend by the funnel into the gullet; and while this is happening the lid is kept closed by the weight of the food and the action of the muscles involved in swallowing. When the food has passed ·and the swallowing stopped·, the natural cartilaginous spring of the lid goes into action, raising the lid a little and allowing a free inlet and outlet for the respiration of air by the lungs. Notice how seldom this expedient fails of its purpose, compared with how often it succeeds. Think how often we swallow, how constantly we breathe, and what a commotion there is when one person allows a crumb or a drop into his windpipe!

This structure cannot have been gradually developed through a succession of generations. The action of the parts has no tendency to form such a thing; and anyway the animal could not live while it was only half formed. The species could not wait for the gradual formation or expansion of a part that was from the outset necessary to the life of the individual.

The whole windpipe has a structure adapted to its particular office. It is made up (as you can perceive by putting your fingers to your throat) of strong cartilaginous ringlets, placed at small and equal distances from one another. These serve to keep the passage for the air constantly open, which they do mechanically. A pipe with soft walls, liable to close when empty, would not have been appropriate here. It is what the body's numerous other conduits are like, and it serves very well for tubes that are kept distended by the fluid they enclose, or provide a passage to solid and protruding substances.

It is notable that these ringlets are not cartilaginous and stiff all around; the part of them that is contiguous to the gullet is membranous and soft, easily yielding to the distentions of the gullet when solid food goes down.

The constitution of the windpipe suggests another reflection. Its inside is lined with what may be the most sensitive, irritable membrane of the body. It reacts to the touch of a crumb of bread or a drop of water with a spasm that convulses the whole frame; yet when it is left to itself and to its proper office of letting in air alone, nothing can be so quiet. It does not even make itself felt; a man does not know that he *has* a trachea. One might have thought it unlikely that a single organ would have both these properties: **a** extreme sensitivity when intruded upon, and **b** perfect rest and ease when left alone. But it is to the combination of these almost inconsistent qualities—in this and some other delicate parts of the body—that we owe our safety and our comfort; our safety to their **a** sensitivity, our comfort to their **b** repose.

[Paley closes the section with some remarks about the role of the lungs and windpipe in song and speech.]

Mechanisms: summing up

Wanting to be methodical, I have considered animal bodies under three divisions—their bones, their muscles, and their vessels—and have made my case in relation to these parts in three separate chapters. But the Creator's wisdom is seen not in their separate but in their collective action, in their mutual subservience and dependence, in their combining to produce single effect. It has been said that a man cannot lift his hand to his head without finding enough to convince him of the existence of a God. That is well said; for he has only to reflect on how many things are needed for performing this familiar and seemingly simple action:

- a long, hard, strong cylinder, to give to the arm its firmness and tension;
- joints for moving the arm, one at the shoulder to raise it and one at the elbow to bend it, these being continually fed with a soft mucilage to make the parts slip easily on one another, and held together by strong braces to keep them in their position;
- muscles and tendons, artfully inserted for the purpose of pulling the bones in the directions the joints allow them to move in.

Up to here we seem to understand the mechanism pretty well; and our understanding of it provides enough for my conclusion. But so far we have only a machine standing still, a dead organisation, an apparatus. To put the system to work, something further must be provided, namely a communication with the brain by means of nerves. We know the existence of this communication, because we can see the communicating threads, and can trace them to the brain; and we also know its necessity, because if the thread is cut, the muscle becomes paralytic. We don't know much more than that, because the organisation is too minute and fine-grained for our inspection.

The single act of a man's raising his hand to his head requires not only all the above but also everything needed for the growth, nourishment and maintenance of the limb, the repair of its waste, the preservation of its health—the circulation of the blood through every part of it; its lymphatics, exhalants, absorbents; its excretions and integuments. All these contribute to the result, join in the effect. It is impossible to conceive how any of these—let alone *all* of them—could collaborate without a designing, disposing intelligence.