

must distinguish fortuitous phenomena about which the calculus of probabilities will provisionally give information, from those which are not fortuitous and of which we can say nothing so long as we shall not have determined the laws governing them. For the fortuitous phenomena themselves, it is clear that the information given us by the calculus of probabilities will not cease to be true upon the day when these phenomena shall be better known.

The director of a life insurance company does not know when each of the insured will die, but he relies upon the calculus of probabilities and on the law of great numbers, and he is not deceived, since he distributes dividends to his stockholders. These dividends would not vanish if a very penetrating and very indiscrete physician should, after the policies were signed, reveal to the director the life chances of the insured. This doctor would dissipate the ignorance of the director, but he would

have no influence on the dividends, which evidently are not an outcome of this ignorance.

Poincaré, *Science and Method*, I, 4

- 51 The greatest bit of chance is the birth of a great man. It is only by chance that meeting of two germinal cells, of different sex, containing precisely, each on its side, the mysterious elements whose mutual reaction must produce the genius. One will agree that these elements must be rare and that their meeting is still more rare. How slight a thing it would have required to deflect from its route the carrying spermatozoon. It would have sufficed to deflect it a tenth of a millimeter and Napoleon would not have been born and the destinies of a continent would have been changed. No example can better make us understand the veritable characteristics of chance.

Poincaré, *Science and Method*, I, 4

19.5 | Motion and Change

At the beginning of Western thought, two pre-Socratic philosophers, Heraclitus and Parmenides, went to the opposite extremes of asserting, on the one hand, that everything is always in flux and never for a moment remains unchanged, and, on the other, that permanence or immutability reigns everywhere and that our experience of motion or change is a deceptive illusion. While they are not quoted here, the views of Heraclitus and Parmenides are commented on by later thinkers who regard motion and rest, or change and permanence, as correlatives, neither of which can be understood without the other.

The philosophical consideration of motion and change attempts to discover its principles (that without which motion or change cannot occur); proposes a classification of the kinds of change, such as local motion, change of quality, or alteration,

change in quantity, or increase and decrease, and what was called “substantial change,” or coming to be and passing away; speculates about whether change or motion ever began and will ever stop or is everlasting, without beginning or end; and asks whether endless motion involves an unmoved mover as its cause.

The modern scientific study of motion—the motion of bodies from place to place—begins with Galileo, and introduces such distinctions as that between natural and violent motion, uniform and variable motion, and such concepts as velocity, acceleration, momentum, and inertia. Employing these concepts, the new sciences of kinematics and dynamics are applied by Newton to the motion of celestial as well as terrestrial bodies. In addition to formulating the principle of inertia as one of his three laws of motion, Newton introduces the concept of gravity,

and the distinction between absolute and relative motion. The reader will be interested to find the existence of absolute motion

challenged by Bishop Berkeley, for reasons that anticipate Einstein's views on the same subject.

- 1 Vanity of vanities, saith the Preacher, vanity of vanities; all is vanity.
 What profit hath a man of all his labour which he taketh under the sun?
 One generation passeth away, and another generation cometh: but the earth abideth for ever.
 The sun also ariseth, and the sun goeth down, and hasteth to his place where he arose.
 The wind goeth toward the south, and turneth about unto the north; it whirleth about continually, and the wind returneth again according to his circuits.
 All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again.
 All things are full of labour; man cannot utter it: the eye is not satisfied with seeing, nor the ear filled with hearing.
 The thing that hath been, it is that which shall be; and that which is done is that which shall be done: and there is no new thing under the sun.
Ecclesiastes 1:2-9
- 2 Can the Ethiopian change his skin, or the leopard his spots?
Jeremiah 13:23
- 3 *Socrates*. Many of our modern philosophers . . . in their search after the nature of things, are always getting dizzy from constantly going round and round, and then they imagine that the world is going round and round and moving in all directions; and this appearance, which arises out of their own internal condition, they suppose to be a reality of nature; they think that there is nothing stable or permanent, but only flux and motion, and that the world is always full of every sort of motion and change.
Plato, Cratylus, 411A
- 4 *Socrates*. Only the self-moving, never-leaving self, never ceases to move, and is the fountain and beginning of motion to all that moves besides. Now, the beginning is unbegotten, for that which is begotten has a beginning; but the beginning is begotten of nothing, for if it were begotten of something, then the begotten would not come from a beginning. But if unbegotten, it must also be indestructible; for if beginning were destroyed, there could be no beginning out of anything, nor anything out of a beginning; and all things must have a beginning. And therefore the self-moving is the beginning of motion; and this can neither
- be destroyed nor begotten, else the whole heavens and all creation would collapse and stand still, and never again have motion or birth.
Plato, Phaedrus, 245B
- 5 Nature has been defined as 'principle of motion and change', and it is the subject of our inquiry. We must therefore see that we understand the meaning of 'motion'; for if it were unknown, the meaning of 'nature' too would be unknown. . . .
The fulfilment of what exists potentially, in so far as it exists potentially, is motion—namely, of what is alterable qua alterable, alteration: of what can be increased and its opposite what can be decreased (there is no common name), increase and decrease: of what can come to be and can pass away, coming to be and passing away: of what can be carried along, locomotion.
Aristotle, Physics, 200^b11
- 6 We must understand that place would not have been thought of, if there had not been a special kind of motion, namely that with respect to place. It is chiefly for this reason that we suppose the heaven also to be in place, because it is in constant movement. Of this kind of change there are two species—locomotion on the one hand and, on the other, increase and diminution. For these too involve variation of place: what was then in this place has now in turn changed to what is larger or smaller.
Aristotle, Physics, 211^a12
- 7 It is a law of nature that earth and all other bodies should remain in their proper places and be moved from them only by violence: from the fact then that some of them are in their proper places it follows that in respect of place also all things cannot be in motion. These and other similar arguments, then, should convince us that it is impossible either that all things are always in motion or that all things are always at rest.
Aristotle, Physics, 253^b33
- 8 Since there must always be motion without intermission, there must necessarily be something, one thing or it may be a plurality, that first imparts motion, and this first movent must be unmoved. Now the question whether each of the things that are unmoved but impart motion is eternal is irrelevant to our present argument: but the following considerations will make it clear that there must necessarily be some such thing, which, while it has

the capacity of moving something else, is itself unmoved and exempt from all change, which can affect it neither in an unqualified nor in an accidental sense. Let us suppose, if any one likes, that in the case of certain things it is possible for them at different times to be and not to be, without any process of becoming and perishing (in fact it would seem to be necessary, if a thing that has not parts at one time is and at another time is not, that any such thing should without undergoing any process of change at one time be and at another time not be). And let us further suppose it possible that some principles that are unmoved but capable of imparting motion at one time are and at another time are not. Even so, this cannot be true of *all* such principles, since there must clearly be something that *causes* things that move themselves at one time to be and at another not to be. For, since nothing that has not parts can be in motion, that which moves itself must as a whole have magnitude, though nothing that we have said makes this necessarily true of every movent. So the fact that some things become and others perish, and that this is so continuously, cannot be caused by any one of those things that, though they are unmoved, do not always exist: nor again can it be caused by any of those which move certain particular things, while others move other things. The eternity and continuity of the process cannot be caused either by any one of them singly or by the sum of them, because this causal relation must be eternal and necessary, whereas the sum of these movents is infinite and they do not all exist together. It is clear, then, that though there may be countless instances of the perishing of some principles that are unmoved but impart motion, and though many things that move themselves perish and are succeeded by others that come into being, and though one thing that is unmoved moves one thing while another moves another, nevertheless there is something that comprehends them all, and that as something apart from each one of them, and this it is that is the cause of the fact that some things are and others are not and of the continuous process of change: and this causes the motion of the other movents, while they are the causes of the motion of other things. Motion, then, being eternal, the first movent, if there is but one, will be eternal also: if there are more than one, there will be a plurality of such eternal movents. We ought, however, to suppose that there is one rather than many, and a finite rather than an infinite number. When the consequences of either assumption are the same, we should always assume that things are finite rather than infinite in number, since in things constituted by nature that which is finite and that which is better ought, if possible, to be present rather than the reverse: and here it is sufficient to assume only one movent, the first of unmoved things, which being

eternal will be the principle of motion to everything else.

Aristotle, *Physics*, 258^b10

- 9 The origin of all other motions [except eternal motion] is that which moves itself, and . . . the origin of this is the immovable, and . . . the prime mover must of necessity be immovable. And we must grasp this not only generally in theory, but also by reference to individuals in the world of sense, for with these in view we seek general theories, and with these we believe that general theories ought to harmonize. Now in the world of sense too it is plainly impossible for movement to be initiated if there is nothing at rest, and before all else in our present subject—animal life. . . . But the point of rest in the animal is still quite ineffectual unless there be something without which is absolutely at rest and immovable. Now it is worth while to pause and consider what has been said, for it involves a speculation which extends beyond animals even to the motion and march of the universe. For just as there must be something immovable within the animal, if it is to be moved, so even more must there be without it something immovable, by supporting itself upon which that which is moved moves. For were that something always to give way (as it does for mice walking in grain or persons walking in sand) advance would be impossible, and neither would there be any walking unless the ground were to remain still, nor any flying or swimming were not the air and the sea to resist. And this which resists must needs be different from what is moved, the whole of it from the whole of that, and what is thus immovable must be no part of what is moved; otherwise there will be no movement.

Aristotle, *On the Motion of Animals*, 698^a11

- 10 Since changes are of four kinds—either in respect of the 'what' or of the quality or of the quantity or of the place, and change in respect of 'thisness' is simple generation and destruction, and change in quantity is increase and diminution, and change in respect of an affection is alteration, and change of place is motion, changes will be from given states into those contrary to them in these several respects. The matter, then, which changes must be capable of both states. And since that which 'is' has two senses, we must say that everything changes from that which is potentially to that which is actually, e.g. from potentially white to actually white, and similarly in the case of increase and diminution. Therefore not only can a thing come to be, incidentally, out of that which is not, but also all things come to be out of that which is, but is potentially, and is not actually.

Aristotle, *Metaphysics*, 1069^b8

- 11 It is necessary that there should be an eternal un-

movable substance. For substances are the first of existing things, and if they are all destructible, all things are destructible. But it is impossible that movement should either have come into being or cease to be (for it must always have existed), or that time should. For there could not be a before and an after if time did not exist. Movement also is continuous, then, in the sense in which time is; for time is either the same thing as movement or an attribute of movement. And there is no continuous movement except movement in place, and of this only that which is circular is continuous.

Aristotle, *Metaphysics*, 1071^b4

- 12 Atoms move continuously for all time, some of them falling straight down, others swerving, and others recoiling from their collisions. And of the latter, some are borne on, separating to a long distance from one another, while others again recoil and recoil, whenever they chance to be checked by the interlacing with others, or else shut in by atoms interlaced around them. For on the one hand the nature of the void which separates each atom by itself brings this about, as it is not able to afford resistance, and on the other hand the hardness which belongs to the atoms makes them recoil after collision to as great a distance as the interlacing permits separation after the collision. And these motions have no beginning, since the atoms and the void are the cause.

Epicurus, *Letter to Herodotus*

- 13 If you think that first-beginnings of things can lag and by lagging give birth to new motions of things, you wander far astray from the path of true reason: since they travel about through void, the first-beginnings of things must all move on either by their own weight or haply by the stroke of another. For when during motion they have, as often happens, met and clashed, the result is a sudden rebounding in an opposite direction; and no wonder, since they are most hard and of weight proportioned to their solidity and nothing behind gets in their way. And that you may more clearly see that all bodies of matter are in restless movement, remember that there is no lowest point in the sum of the universe, and that first bodies have not where to take their stand, since space is without end and limit and extends immeasurably in all directions round, as I have shown in many words and as has been proved by sure reason.

Lucretius, *Nature of Things*, II

- 14 The earth with good title has gotten and keeps the name of mother, since she of herself gave birth to mankind and at a time nearly fixed shed forth every beast that ranges wildly over the great mountains, and at the same time the fowls of the air with all their varied shapes. But because she must have some limit set to her bearing, she ceased like a woman worn out by length of days.

For time changes the nature of the whole world and all things must pass on from one condition to another, and nothing continues like to itself: all things quit their bounds, all things nature changes and compels to alter. One thing crumbles away and is worn and enfeebled with age, then another comes unto honour and issues out of its state of contempt. In this way then time changes the nature of the whole world and the earth passes out of one condition into another: what once it could, it can bear no more, in order to be able to bear what before it did not bear.

Lucretius, *Nature of Things*, V

- 15 Often think of the rapidity with which things pass by and disappear, both the things which are and the things which are produced. For substance is like a river in a continual flow, and the activities of things are in constant change, and the causes work in infinite varieties; and there is hardly anything which stands still.

Marcus Aurelius, *Meditations*, V, 23

- 16 Some things are hurrying into existence, and others are hurrying out of it; and of that which is coming into existence part is already extinguished. Motions and changes are continually renewing the world, just as the uninterrupted course of time is always renewing the infinite duration of ages. In this flowing stream then, on which there is no abiding, what is there of the things which hurry by on which a man would set a high price? It would be just as if a man should fall in love with one of the sparrows which fly by, but it has already passed out of sight.

Marcus Aurelius, *Meditations*, VI, 15

- 17 Is any man afraid of change? Why what can take place without change? What then is more pleasing or more suitable to the universal nature? And canst thou take a bath unless the wood undergoes a change? And canst thou be nourished, unless the food undergoes a change? And can anything else that is useful be accomplished without change? Dost thou not see then that for thyself also to change is just the same, and equally necessary for the universal nature?

Marcus Aurelius, *Meditations*, VII, 18

- 18 When . . . such and such a body undergoes no change from its existing state, we say that it is at rest; but, if it departs from this in any respect we then say that in this respect it undergoes motion. Accordingly, when it departs in various ways from its pre-existing state, it will be said to undergo various kinds of motion. Thus, if that which is white becomes black, or what is black becomes white, it undergoes motion in respect to colour. . . . And further, it is not only things which are altered in regard to colour and flavour which, we say, undergo motion; when a warm thing becomes

cold, and a cold warm, here too we speak of its undergoing motion; similarly also when anything moist becomes dry, or dry moist. Now, the common term which we apply to all these cases is alteration.

This is one kind of motion. But there is another kind which occurs in bodies which change their position, or as we say, pass from one place to another; the name of this is transference.

These two kinds of motion, then, are simple and primary, while compounded from them we have growth and decay, as when a small thing becomes bigger, or a big thing smaller, each retaining at the same time its particular form. And two other kinds of motion are genesis and destruction, genesis being a coming into existence, and destruction being the opposite.

Galen, *Natural Faculties*, I, 2

- 19 The Kosmos has had no beginning . . . and this is warrant for its continued existence. Why should there be in the future a change that has not yet occurred? The elements there are not worn away like beams and rafters: they hold sound for ever, and so the All holds sound. And even supposing these elements to be in ceaseless transmutation, yet the All persists: the ground of all the change must itself be changeless.

Plotinus, *Second Ennead*, I, 4

- 20 It is certain, and evident to our senses, that in this world some things are in motion. Now whatever is in motion is put in motion by another, for nothing can be in motion unless it is in potency to that towards which it is in motion. But a thing moves in so far as it is in act. For motion is nothing else than the reduction of something from potency to act. But nothing can be reduced from potency to act except by something in a state of act. Thus that which is actually hot, as fire, makes wood, which is potentially hot, to be actually hot, and thereby moves and changes it. Now it is not possible that the same thing should be at once in act and potency in the same respect, but only in different respects. For what is actually hot cannot simultaneously be potentially hot, though it is simultaneously potentially cold. It is therefore impossible that in the same respect and in the same way a thing should be both mover and moved, that is, that it should move itself. Therefore, whatever is moved must be moved by another. If that by which it is moved be itself moved, then this also must be moved by another, and that by another again. But this cannot go on to infinity, because then there would be no first mover, and, consequently, no other mover, seeing that subsequent movers move only because as they are moved by the first mover, just as the staff moves only because it is moved by the hand. Therefore it is necessary to arrive at a first mover which is

moved by no other. And this everyone understands to be God.

Aquinas, *Summa Theologica*, I, 2, 3

- 21 Now it is manifest that a natural body cannot be actually infinite . . . because every natural body has some natural movement. But an infinite body could not have any natural movement. Neither direct, because nothing moves naturally by a direct movement unless it is out of its place, and this could not happen to an infinite body, for it would occupy every place, and thus every place would be indifferently its own place. Neither could it move circularly; since circular motion requires that one part of the body is necessarily transferred to a place occupied by another part, and this could not happen as regards an infinite circular body; for if two lines be drawn from the centre, the farther they extend from the centre, the farther they are from each other; therefore, if a body were infinite, the lines would be infinitely distant from each other, and thus one could never reach the place belonging to any other.

Aquinas, *Summa Theologica*, I, 7, 3

- 22 In the sense . . . in which understanding is movement, that which understands itself is said to move itself.

Aquinas, *Summa Theologica*, I, 18, 3

- 23 Rest is, properly speaking, opposed to movement, and consequently to the labour that arises from movement. But although movement, strictly speaking, is a quality of bodies, yet the word is applied also to spiritual things, and in a twofold sense. On the one hand, every operation may be called a movement, and thus the Divine goodness is said to move and go forth to the thing in communicating itself to that thing. . . . On the other hand, the desire that tends to another, is said to move towards it. Hence rest is taken in two senses, in one sense meaning a cessation from work, in the other, the fulfilling of desire.

Aquinas, *Summa Theologica*, I, 73, 2

- 24 I myself think that gravity or heaviness is nothing except a certain natural appetency implanted in the parts by the divine providence of the universal Artisan, in order that they should unite with one another in their oneness and wholeness and come together in the form of a globe. It is believable that this affect is present in the sun, moon, and the other bright planets and that through its efficacy they remain in the spherical figure in which they are visible, though they nevertheless accomplish their circular movements in many different ways.

Copernicus, *De Revolutionibus*, I, 9

- 25 In all things except those that are simply bad, change is to be feared: change of seasons, winds, food, and humors. And no laws are held in their

true honor except those to which God has given some ancient duration, so that no one knows their origin or that they were ever different.

Montaigne, *Essays*, I, 43, Of
Sumptuary Laws

- 26 When I bethinke me on that speech whyleare
Of Mutability, and well it way,
Me seemes, that though she all unworthy were
Of the heav'ns rule, yet, very sooth to say,
In all things else she beares the greatest sway:
Which makes me loath this state of life so tickle,
And love of things so vaine to cast away;
Whose flowring pride, so fading and so fickle,
Short Time shall soon cut down with his consum-
ing sickle.
- Then gin I thinke on that which Nature sayd,
Of that same time when no more change shall be,
But stedfast rest of all things, firmly stayd
Upon the pillours of eternity,
That is contrayr to Mutabilitie:
For all that moveth doth in change delight:
But thence-forth all shall rest eternally
With Him that is the God of Sabbaoth hight:
O that great Sabbaoth God graunt me that Sab-
baoths sight!
Spenser, *Faerie Queene*, Bk. VII, VIII, 1-2
- 27 As regards movement: the sun is the first cause of the movement of the planets and the first mover of the universe, even by reason of its own body. In the intermediate space the movables, i.e., the globes of the planets, are laid out. The region of the fixed stars supplies the movables with a place and a base upon which the movables are, as it were, supported; and movement is understood as taking place relative to its absolute immobility. So in animals the cerebellum is the seat of the motor faculty, and the body and its members are that which is moved. The Earth is the base of an animal body; the body, the base of the arm or head, and the arm, the base of the finger. And the movement of each part takes place upon this base as upon something immovable.
- Kepler, *Epitome of Copernican Astronomy*, Bk. IV, I, 1
- 28 *Ariel*. [Sings] Full fathom five thy father lies;
Of his bones are coral made;
Those are pearls that were his eyes:
Nothing of him that doth fade
But doth suffer a sea-change
Into something rich and strange.
Sea-nymphs hourly ring his knell.
Shakespeare, *Tempest*, I, ii, 396
- 29 When I have seen by Time's fell hand defaced
The rich proud cost of outworn buried age;
When sometime lofty towers I see down-razed
And brass eternal slave to mortal rage;
- When I have seen the hungry ocean gain
Advantage on the kingdom of the shore,
And the firm soil win of the watery main,
Increasing store with loss and loss with store;
When I have seen such interchange of state,
Or state itself confounded to decay;
Ruin hath taught me thus to ruminare,
That Time will come and take my love away.
Shakespeare, *Sonnet LXIV*
- 30 To think the Affairs of this Life are always to remain in the same State, is an erroneous Fancy. The Face of Things rather seems continually to change and roll with a circular Motion; Summer succeeds the Spring; Autumn the Summer; Winter the Autumn; and then Spring again: So Time proceeds in this perpetual Round; only the Life of Man is ever hastening to it's End, swifter than Time it self, without Hopes to be renew'd, unless in the next, that is unlimited and infinite.
- Cervantes, *Don Quixote*, II, 53
- 31 All motion or natural action takes place in time, more or less rapidly, but still in determined moments well ascertained by nature. Even those actions which appear to take effect suddenly, and in the twinkling of an eye (as we express it), are found to admit of greater or less rapidity.
- Bacon, *Novum Organum*, II, 46
- 32 One which can scarcely be termed a motion, and yet is one . . . we may call the motion of repose, or of abhorrence of motion. It is by this motion that the earth stands by its own weight, whilst its extremes move towards the middle, not to an imaginary centre, but in order to unite. It is owing to the same tendency, that all bodies of considerable density abhor motion, and their only tendency is not to move, which nature they preserve, although excited and urged in a variety of ways to motion. But if they be compelled to move, yet do they always appear anxious to recover their former state, and to cease from motion, in which respect they certainly appear active, and attempt it with sufficient swiftness and rapidity, as if fatigued, and impatient of delay.
- Bacon, *Novum Organum*, II, 48
- 33 As the births of living creatures at first are ill-shapen, so are all innovations, which are the births of time.
- Bacon, *Of Innovations*
- 34 It were good . . . that men in their innovations would follow the example of time itself, which indeed innovateth greatly, but quietly and by degrees scarce to be perceived.
- Bacon, *Of Innovations*
- 35 It is a secret, both in nature and state, that it is safer to change many things than one.
- Bacon, *Of Regiment of Health*

- 36 The variation of speed observed in bodies of different specific gravities is not caused by the difference of specific gravity but depends upon external circumstances and, in particular, upon the resistance of the medium, so that if this is removed all bodies would fall with the same velocity.
Galileo, *Two New Sciences*, I
- 37 There is, in nature, perhaps nothing older than motion, concerning which the books written by philosophers are neither few nor small; nevertheless, I have discovered by experiment some properties of it which are worth knowing and which have not hitherto been either observed or demonstrated. Some superficial observations have been made, as, for instance, that the free motion of a heavy falling body is continuously accelerated; but to just what extent this acceleration occurs has not yet been announced; for so far as I know, no one has yet pointed out that the distances traversed, during equal intervals of time, by a body falling from rest, stand to one another in the same ratio as the odd numbers beginning with unity.
It has been observed that missiles and projectiles describe a curved path of some sort; however, no one has pointed out the fact that this path is a parabola. But this and other facts, not few in number or less worth knowing, I have succeeded in proving; and what I consider more important, there have been opened up to this vast and most excellent science, of which my work is merely the beginning, ways and means by which other minds more acute than mine will explore its remote corners.
Galileo, *Two New Sciences*, III
- 38 Any velocity once imparted to a moving body will be rigidly maintained as long as the external causes of acceleration or retardation are removed, a condition which is found only on horizontal planes; for in the case of planes which slope downwards there is already present a cause of acceleration, while on planes sloping upward there is retardation; from this it follows that motion along a horizontal plane is perpetual; for, if the velocity be uniform, it cannot be diminished or slackened, much less destroyed.
Galileo, *Two New Sciences*, III
- 39 That when a thing lies still, unless somewhat else stir it, it will lie still for ever, is a truth that no man doubts of. But that when a thing is in motion, it will eternally be in motion, unless somewhat else stay it, though the reason be the same (namely, that nothing can change itself), is not so easily assented to.
Hobbes, *Leviathan*, I, 2
- 40 He no longer loves the person whom he loved ten years ago. I quite believe it. She is no longer the same, nor is he. He was young, and she also; she is quite different. He would perhaps love her yet, if she were what she was then.
Pascal, *Pensées*, II, 123
- 41 Geometry supposes . . . that we know what thing is meant by the words: *motion, number, space*; and without stopping uselessly to define them it penetrates their nature and lays bare their marvelous properties.
These three things, which comprise the entire universe . . . are reciprocally and necessarily related. For we cannot imagine a motion without something which moves, and this thing being one, that unity is the origin of all number. Finally, since motion is impossible without space, we see that these three things are contained in the first. Even time is included there too, for motion and time are correlative (*fast and slow, which differentiate motion, having a necessary reference to time*).
Pascal, *Geometrical Demonstration*
- 42 However fast a motion may be, we can conceive a faster, and make that still faster, and thus forever to infinity without ever reaching a motion so fast that we can no longer add to it. And on the contrary, however slow a motion may be, we can make it slower, and that still slower, and so to infinity without ever reaching such a degree of slowness that we cannot still descend to an infinity of lower degrees without falling into rest.
Pascal, *Geometrical Demonstration*
- 43 If two contrary actions be excited in the same subject, a change must necessarily take place in both, or in one alone, until they cease to be contrary.
Spinoza, *Ethics*, V, Axiom 1
- 44 It is inconceivable to doubt that light consists in the motion of some sort of matter. For whether one considers its production, one sees that here upon the earth it is chiefly engendered by fire and flame which contain without doubt bodies that are in rapid motion, since they dissolve and melt many other bodies, even the most solid; or whether one considers its effects, one sees that when light is collected, as by concave mirrors, it has the property of burning as a fire does, that is to say, it disunites the particles of bodies. This is assuredly the mark of motion, at least in the true philosophy, in which one conceives the causes of all natural effects in terms of mechanical motions. This, in my opinion, we must necessarily do, or else renounce all hopes of ever comprehending anything in physics.
Huygens, *Treatise on Light*, I
- 45 The *vis insita*, or innate force of matter, is a power of resisting, by which every body, as much as in it

lies, continues in its present state, whether it be of rest, or of moving uniformly forwards in a right line. This force is always proportional to the body whose force it is and differs nothing from the inactivity of the mass, but in our manner of conceiving it. A body, from the inert nature of matter, is not without difficulty put out of its state of rest or motion. Upon which account, this *vis insita* may, by a most significant name, be called inertia or force of inactivity. But a body only exerts this force when another force, impressed upon it, endeavors to change its condition; and the exercise of this force may be considered as both resistance and impulse; it is resistance so far as the body, for maintaining its present state, opposes the force impressed; it is impulse so far as the body, by not easily giving way to the impressed force of another, endeavors to change the state of that other. Resistance is usually ascribed to bodies at rest, and impulse to those in motion; but motion and rest, as commonly conceived, are only relatively distinguished; nor are those bodies always truly at rest, which commonly are taken to be so.

Newton, *Principia*, Definition III

- 46 Absolute motion is the translation of a body from one absolute place into another; and relative motion, the translation from one relative place into another. Thus in a ship under sail, the relative place of a body is that part of the ship which the body possesses; or that part of the cavity which the body fills, and which therefore moves together with the ship: and relative rest is the continuance of the body in the same part of the ship, or of its cavity. But real, absolute rest, is the continuance of the body in the same part of that immovable space, in which the ship itself, its cavity, and all that it contains, is moved. Wherefore, if the earth is really at rest, the body, which relatively rests in the ship, will really and absolutely move with the same velocity which the ship has on the earth. But if the earth also moves, the true and absolute motion of the body will arise, partly from the true motion of the earth, in immovable space, partly from the relative motion of the ship on the earth; and if the body moves also relatively in the ship, its true motion will arise, partly from the true motion of the earth, in immovable space, and partly from the relative motions as well of the ship on the earth, as of the body in the ship; and from these relative motions will arise the relative motion of the body on the earth. As if that part of the earth, where the ship is, was truly moved towards the east, with a velocity of 10,010 parts; while the ship itself, with a fresh gale, and full sails, is carried towards the west, with a velocity expressed by 10 of those parts; but a sailor walks in the ship towards the east, with 1 part of the said velocity; then the sailor will be moved truly in immovable space towards the east, with a velocity of 10,001 parts, and relatively on the earth towards the

west, with a velocity of 9 of those parts.

Newton, *Principia*, Definitions, Scholium

- 47 Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it. Projectiles continue in their motions, so far as they are not retarded by the resistance of the air, or impelled downwards by the force of gravity. A top, whose parts by their cohesion are continually drawn aside from rectilinear motions, does not cease its rotation, otherwise than as it is retarded by the air. The greater bodies of the planets and comets, meeting with less resistance in freer spaces, preserve their motions both progressive and circular for a much longer time.

The change of motion is proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed. If any force generates a motion, a double force will generate double the motion, a triple force triple the motion, whether that force be impressed altogether and at once, or gradually and successively. And this motion (being always directed the same way with the generating force), if the body moved before, is added to or subtracted from the former motion, according as they directly conspire with or are directly contrary to each other; or obliquely joined, when they are oblique, so as to produce a new motion compounded from the determination of both.

To every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts. Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone; for the distended rope, by the same endeavor to relax or unbend itself, will draw the horse as much towards the stone as it does the stone towards the horse, and will obstruct the progress of the one as much as it advances that of the other. If a body impinge upon another, and by its force change the motion of the other, that body also (because of the equality of the mutual pressure) will undergo an equal change, in its own motion, towards the contrary part. The changes made by these actions are equal, not in the velocities but in the motions of bodies; that is to say, if the bodies are not hindered by any other impediments. For, because the motions are equally changed, the changes of the velocities made towards contrary parts are inversely proportional to the bodies. This law takes place also in attractions, as will be proved in the next Scholium.

Newton, *Principia*, Axioms I-III

- 48 If spheres be however dissimilar (as to density of

matter and attractive force) in the same ratio on-wards from the centre to the circumference; but everywhere similar, at every given distance from the centre, on all sides round about; and the attractive force of every point decreases as the square of the distance of the body attracted: I say, that the whole force with which one of these spheres attracts the other will be inversely proportional to the square of the distance of the centres.

Newton, *Principia*, I, 12

- 49 If it universally appears, by experiments and astronomical observations, that all bodies about the earth gravitate towards the earth, and that in proportion to the quantity of matter which they severally contain; that the moon likewise, according to the quantity of its matter, gravitates towards the earth; that, on the other hand, our sea gravitates towards the moon; and all the planets one towards another; and the comets in like manner towards the sun; we must, in consequence of this rule, universally allow that all bodies whatsoever are endowed with a principle of mutual gravitation. For the argument from the appearances concludes with more force for the universal gravitation of all bodies than for their impenetrability; of which, among those in the celestial regions, we have no experiments, nor any manner of observation. Not that I affirm gravity to be essential to bodies: by their *vis insita* I mean nothing but their inertia. This is immutable. Their gravity is diminished as they recede from the earth.

Newton, *Principia*, III, Rule III

- 50 There is . . . [an] idea, which, though suggested by our senses, yet is more constantly offered to us by what passes in our minds; and that is the idea of *succession*. For if we look immediately into ourselves, and reflect on what is observable there, we shall find our ideas always, whilst we are awake, or have any thought, passing in train, one going and another coming, without intermission.

Locke, *Concerning Human Understanding*,
Bk. II, VII, 9

- 51 Modes of motion answer those of extension; swift and slow are two different ideas of motion, the measures whereof are made of the distances of time and space put together; so they are complex ideas, comprehending time and space with motion.

Locke, *Concerning Human Understanding*,
Bk. II, XVIII, 2

- 52 We have ideas but of two sorts of action, viz. motion and thinking. These, in truth, though called and counted actions, yet, if nearly considered, will not be found to be always perfectly so. For, if I mistake not, there are instances of both kinds, which, upon due consideration, will be found rather passions than actions; and consequently so

far the effects barely of *passive powers* in those subjects, which yet on their accounts are thought agents. For, in these instances, the substance that hath motion or thought receives the impression, whereby it is put into that action, purely from without, and so acts merely by the capacity it has to receive such an impression from some external agent; and such power is not properly an active power, but a mere passive capacity in the subject. Sometimes the substance or agent puts itself into action by its own power, and this is properly *active power*. Whatsoever modification a substance has, whereby it produces any effect, that is called action: v.g. a solid substance, by motion, operates on or alters the sensible ideas of another substance, and therefore this modification of motion we call action. But yet this motion in that solid substance is, when rightly considered, but a passion, if it received it only from some external agent. So that the active power of motion is in no substance which cannot begin motion in itself or in another substance when at rest.

Locke, *Concerning Human Understanding*,
Bk. II, XXI, 74

- 53 It does not appear to me that there can be any motion other than *relative*; so that to conceive motion there must be at least conceived two bodies, whereof the distance or position in regard to each other is varied. Hence, if there was one only body in being it could not possibly be moved. This seems evident, in that the idea I have of motion doth necessarily include relation.

But, though in every motion it be necessary to conceive more bodies than one, yet it may be that one only is moved, namely, that on which the force causing the change in the distance or situation of the bodies, is impressed. For, however some may define relative motion, so as to term that body *moved* which changes its distance from some other body, whether the force or action causing that change were impressed on it or no, yet as relative motion is that which is perceived by sense, and regarded in the ordinary affairs of life, it should seem that every man of common sense knows what it is as well as the best philosopher. Now, I ask any one whether, in his sense of motion as he walks along the streets, the stones he passes over may be said to *move*, because they change distance with his feet? To me it appears that though motion includes a relation of one thing to another, yet it is not necessary that each term of the relation be denominated from it. As a man may think of somewhat which does not think, so a body may be moved to or from another body which is not therefore itself in motion.

As the place happens to be variously defined, the motion which is related to it varies. A man in a ship may be said to be quiescent with relation to the sides of the vessel, and yet move with relation to the land. Or he may move eastward in respect

of the one, and westward in respect of the other. In the common affairs of life men never go beyond the earth to define the place of any body; and what is quiescent in respect of that is accounted *absolutely* to be so. But philosophers, who have a greater extent of thought, and juster notions of the system of things, discover even the earth itself to be moved. In order therefore to fix their notions they seem to conceive the corporeal world as finite, and the utmost unmoved walls or shell thereof to be the place whereby they estimate true motions. If we sound our own conceptions, I believe we may find all the absolute motion we can frame an idea of to be at bottom no other than relative motion thus defined. For, as hath been already observed, absolute motion, exclusive of all external relation, is incomprehensible; and to this kind of relative motion all the above-mentioned properties, causes, and effects ascribed to absolute motion will, if I mistake not, be found to agree.

Berkeley, *Principles of Human Knowledge*, 112–114

- 54 Be not the first by whom the new are tried,
Nor yet the last to lay the old aside.
Pope, *Essay on Criticism*, II, 335
- 55 The more communicative a people are, the more easily they change their habits, because each is in a greater degree a spectacle to the other and the singularities of individuals are better observed. The climate which influences one nation to take pleasure in being communicative, makes it also delight in change, and that which makes it delight in change forms its taste.
Montesquieu, *Spirit of Laws*, XIX, 8
- 56 To begin with the examination of motion; 'tis evident this is a quality altogether inconceivable alone, and without a reference to some other object. The idea of motion necessarily supposes that of a body moving. Now what is our idea of the moving body, without which motion is incomprehensible? It must resolve itself into the idea of extension or of solidity; and consequently the reality of motion depends upon that of these other qualities.
Hume, *Treatise of Human Nature*, Bk. I, IV, 4
- 57 A man used to vicissitudes is not easily dejected.
Johnson, *Rasselas*, XII
- 58 Such, said Nekayah, is the state of life, that none are happy but by the anticipation of change: the change itself is nothing; when we have made it, the next wish is to change again.
Johnson, *Rasselas*, XLVII
- 59 *Johnson*. When I was a young man, being anxious to distinguish myself, I was perpetually starting

new propositions. But I soon gave this over; for, I found that generally what was new was false.

Boswell, *Life of Johnson* (Mar. 26, 1779)

60 The permanent in phenomena must be regarded as the substratum of all determination of time, and consequently also as the condition of the possibility of all synthetical unity of perceptions, that is, of experience; and all existence and all change in time can only be regarded as a mode in the existence of that which abides unchangeably. Therefore, in all phenomena, the permanent is the object *in itself*; that is, the substance; but all that changes or can change belongs only to the mode of the existence of this substance or substances, consequently to its determinations.

I find that in all ages not only the philosopher, but even the common understanding, has preposited this permanence as a substratum of all change in phenomena; indeed, I am compelled to believe that they will always accept this as an indubitable fact. Only the philosopher expresses himself in a more precise and definite manner, when he says: "In all changes in the world, the *substance* remains, and the *accidents* alone are changeable." But of this decidedly synthetical proposition, I nowhere meet with even an attempt at proof; nay, it very rarely has the good fortune to stand, as it deserves to do, at the head of the pure and entirely *a priori* laws of nature. In truth, the statement that substance is permanent, is tautological. For this very permanence is the ground on which we apply the category of substance to the phenomenon; and we should have been obliged to prove that in all phenomena there is something permanent, of the existence of which the changeable is nothing but a determination. But because a proof of this nature cannot be dogmatical, that is cannot be drawn from conceptions, inasmuch as it concerns a synthetical proposition *a priori*, and as philosophers never reflected that such propositions are valid only in relation to possible experience, and therefore cannot be proved except by means of a deduction of the possibility of experience, it is no wonder that while it has served as the foundation of all experience (for we feel the need of it in empirical cognition), it has never been supported by proof.

Kant, *Critique of Pure Reason*,
Transcendental Analytic

61 In order to represent *change* as the intuition corresponding to the conception of causality, we require the representation of motion as change in space; in fact, it is through it alone that changes, the possibility of which no pure understanding can perceive, are capable of being intuited. Change is the connection of determinations contradictorily opposed to each other in the existence of one and the same thing. Now, how it is possible that out of a given state one quite opposite to it in

the same thing should follow, reason without an example can not only not conceive, but cannot even make intelligible without intuition; and this intuition is the motion of a point in space; the existence of which in different spaces (as a consequence of opposite determinations) alone makes the intuition of change possible. For, in order to make even internal change cognitable, we require to represent time, as the form of the internal sense, figuratively by a line, and the internal change by the drawing of that line (motion), and consequently are obliged to employ external intuition to be able to represent the successive existence of ourselves in different states. The proper ground of this fact is that all change to be perceived as change presupposes something permanent in intuition, while in the internal sense no permanent intuition is to be found.

Kant, *Critique of Pure Reason*,
Transcendental Analytic

- 62 The changes that take place in nature—how infinitely manifold soever they may be—exhibit only a perpetually self-repeating cycle; in nature there happens “nothing new under the sun,” and the multifarious play of its phenomena so far induces a feeling of *ennui*; only in those changes which take place in the region of spirit does anything new arise.
- Hegel, *Philosophy of History*,
Introduction, 3
- 63 Let the great world spin for ever down the ringing grooves of change.
- Tennyson, *Locksley Hall*, 182
- 64 Arthur. The old order changeth, yielding place to new,
And God fulfils himself in many ways,
Lest one good custom should corrupt the world.
- Tennyson, *The Passing of Arthur*, 408
- 65 All change is a miracle to contemplate; but it is a miracle which is taking place every instant.
- Thoreau, *Walden: Economy*
- 66 Suppose we were able, within the length of a second, to note 10,000 events distinctly, instead of barely 10, as now; if our life were then destined to hold the same number of impressions, it might be 1000 times as short. We should live less than a month, and personally know nothing of the change of seasons. If born in winter, we should believe in summer as we now believe in the heats of the Carboniferous era. The motions of organic beings would be so slow to our senses as to be inferred, not seen. The sun would stand still in the sky, the moon be almost free from change, and so on. But now reverse the hypothesis and suppose a being to get only one 1000th part of the sensations that we get in a given time, and consequently to live 1000 times as long. Winters and summers will be to him like quarters of an hour. Mushrooms and the swifter-growing plants will shoot into being so rapidly as to appear instantaneous creations; annual shrubs will rise and fall from the earth like restlessly boiling-water springs; the motions of animals will be as invisible as are to us the movements of bullets and cannon-balls; the sun will scour through the sky like a meteor, leaving a fiery trail behind him, etc. That such imaginary cases (barring the superhuman longevity) may be realized somewhere in the animal kingdom, it would be rash to deny.
- William James, *Psychology*, XV
- 67 Newton in his description of space and time has confused what is ‘real’ potentiality with what is actual fact. He has thereby been led to diverge from the judgment of ‘the vulgar’ who ‘conceive those quantities under no other notions but from the relation they bear to sensible objects.’ The philosophy of organism starts by agreeing with ‘the vulgar’ except that the term ‘sensible object’ is replaced by ‘actual entity’; so as to free our notions from participation in an epistemological theory as to sense-perception. When we further consider how to adjust Newton’s other descriptions to the organic theory, the surprising fact emerges that we must identify the atomized quantum of extension correlative to an actual entity, with Newton’s absolute place and absolute duration. Newton’s proof that motion does not apply to absolute place, which in its nature is immovable, also holds. Thus an actual entity never moves: it is where it is and what it is. In order to emphasize this characteristic by a phrase connecting the notion of ‘actual entity’ more closely with our ordinary habits of thought, I will also use the term ‘actual occasion’ in the place of the term ‘actual entity.’ Thus the actual world is built up of actual occasions; and by the ontological principle whatever things there are in any sense of ‘existence,’ are derived by abstraction from actual occasions. I shall use the term ‘event’ in the more general sense of a nexus of actual occasions, interrelated in some determinate fashion in one extensive quantum. An actual occasion is the limiting type of an event with only one member.
- It is quite obvious that meanings have to be found for the notions of ‘motion’ and of ‘moving bodies’ . . . It is sufficient to say that a molecule in the sense of a moving body, with a history of local change, is not an actual occasion; it must therefore be some kind of nexus of actual occasions. In this sense it is an event, but not an actual occasion. The fundamental meaning of the notion of ‘change’ is ‘the difference between actual occasions comprised in some determinate event.’
- Whitehead, *Process and Reality*, II, 2
- 68 This subject of the formation of the three laws of

motion and of the law of gravitation deserves critical attention. The whole development of thought occupied exactly two generations. It commenced with Galileo and ended with Newton's *Principia*; and Newton was born in the year that Galileo died. Also the lives of Descartes and Huygens fall within the period occupied by these great terminal figures. The issue of the combined labours of these four men has some right to be considered as the greatest single intellectual success which mankind has achieved. In estimating its size, we must consider the completeness of its range. It constructs for us a vision of the material universe, and it enables us to calculate the minutest detail of a particular occurrence. Galileo took the first step in hitting on the right line of thought. He noted that the critical point to attend to was not the motion of bodies but the changes of their motions. Galileo's discovery is formularised by Newton in his first law of motion:—'Every body continues in its state of rest, or of uniform motion in a straight line, except so far as it may be compelled by force to change that state.'

This formula contains the repudiation of a belief which had blocked the progress of physics for two thousand years.

Whitehead, *Science and the Modern World*, III

69 Perhaps the most powerful solvent of the pre-scientific outlook has been the first law of motion, which the world owes to Galileo, though to some extent he was anticipated by Leonardo da Vinci.

The first law of motion says that a body which is moving will go on moving in the same direction with the same velocity until something stops it. Before Galileo it had been thought that a lifeless body will not move of itself, and if it is in motion it will gradually come to rest. Only living beings, it was thought, could move without help of some external agency. Aristotle thought that the heavenly bodies were pushed by gods. Here on earth, animals can set themselves in motion and can cause motion in dead matter. There are, it was conceded, certain kinds of motion which are "natural" to dead matter: earth and water naturally move downwards, air and fire upwards; but beyond these simple "natural" motions everything depends upon impulsion from the souls of living beings.

So long as this view prevailed, physics as an independent science was impossible, since the physical world was thought to be not causally self-contained. But Galileo and Newton between them proved that all the movements of the planets, and of dead matter on the earth, proceed according to the laws of physics, and once started, will continue indefinitely. There is no need of mind in this process. Newton still thought that a Creator was necessary to get the process going, but that after that He left it to work according to its own laws.

Russell, *Science and Tradition*

70 Motion consists merely in the fact that bodies are sometimes in one place and sometimes in another, and that they are at intermediate places at intermediate times. Only those who have waded through the quagmire of philosophic speculation on this subject can realize what a liberation from antique prejudices is involved in this simple and straightforward commonplace.

Russell, *Mathematics and the Metaphysicians*

71 With slight exaggeration, it may be said that the thoroughgoing way in which Aristotle defined, distinguished and classified rest and movement, the finished and the incomplete, the actual and potential, did more to fix tradition, the genteel tradition one is tempted to add, which identifies the fixed and regular with reality of Being and the changing and hazardous with deficiency of Being than ever was accomplished by those who took the shorter path of asserting that change is illusory.

Dewey, *Experience and Nature*, II

72 I believe that if one were convinced of the reality of change and if one made an effort to grasp it, everything would become simplified, philosophical difficulties, considered insurmountable, would fall away. Not only would philosophy gain by it, but our everyday life—I mean the impression things make upon us and the reaction of our intelligence, our sensibility and our will upon things—would perhaps be transformed and, as it were, transfigured. The point is that usually we look at change but we do not see it. We speak of change, but we do not think about it. We say that change exists, that everything changes, that change is the very law of things: yes, we say it and we repeat it; but those are only words, and we reason and philosophise as though change did not exist.

Bergson, *The Creative Mind*, V

73 Only haste and lack of circumspection in conceiving what spirit is and how it moves could assign to it the origin of change. On the contrary, while spirit is extraordinarily mobile in its existence, it borrows this mobility from the hair-trigger organisation and unstable equilibrium of its organs, and of the stimulations which excite them incessantly. In its own nature, spirit arrests the flux of things, as best it may, in its intuitions, and turns it into a store of synthetic pictures and symbols, sensuous and intellectual. We may therefore say with more reason that the world imposes movement on a spirit which by its own genius would rather be addressed to the eternal, than say that reality seems successive only to a flighty spirit, turning distractedly the leaves of a book written in eternity. Matter, not spirit, is the seat and principle of the flux. Spirit, being an emanation of this flux, seems indeed a pilgrim wandering and almost lost in the wilderness of essence and in the dark treasure-house of truth; but in respect to the realm of