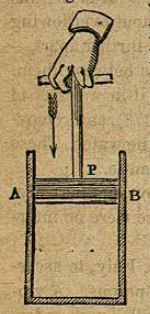
duced. A sponge, for instance, by the simple pressure of the hand, can be reduced to one-tenth of its natural size. In like manner, if the pores of a body are made larger by any agency (as they are by heat), its size is proportionately increased.

Fig. 8.



30. All bodies possess these properties. A rod of iron, too large to enter a certain opening, may be so compressed by hammering as to pass through it, and then so expanded by heat as to render its entrance again impossible. Liquids, which were long considered incompressible, are now known to yield to a high degree of pressure; their expansibility is illustrated by the rise of mercury in the thermometer.

The compressibility and expansibility of air are shown by the apparatus represented in Fig. 8. Let P be a piston, fitted, air-tight, to the cylinder A B. As the piston is driven down, the air, unable to escape, is compressed; as it is drawn back, the air expands.

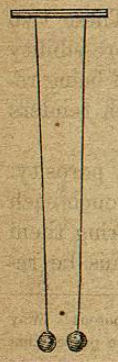
Aëriform bodies are more easily compressed and expanded than any others.

31. Mobility.—Mobility is that property which renders a body capable of being moved.

Though the inertia of bodies prevents them from moving themselves, yet there is no body that can not be moved by the application of a proper force.

32. Gravitation.—Gravitation (or Gravity, as it is called when acting at short distances) is the tendency which one body has to approach another, under the influence of the latter's attraction. A cannon ball dropped from the hand falls to the earth by reason of its gravity. The earth at the same time moves towards the cannon ball, but through a space inconceivably small in consequence of its vast superiority in size over the ball.

Fig. 9.



That the cannon ball is capable of attracting as well as being attracted, may be proved by suspending two balls close to each other by very long cords. In consequence of the attraction of the balls, the cords will not hang parallel, but will incline towards each other as they descend, as shown in Fig. 9.

follow from porosity. 30. How may compressibility and expansibility be illustrated with an iron rod? What is said of these properties in liquids? How may the compressibility and expansibility of air be shown? What bodies are most easily com-

We now proceed to the Accessory Properties, which are confined to certain bodies.

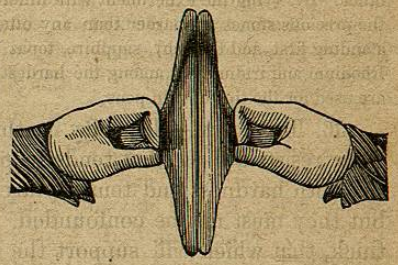
33. Cohesion.—Cohesion is that property by which the particles of a body cling to each other. As particles are also called *mol'-e-cules*, Cohesion has received from some authors the name of Mo-lec'-u-lar Attraction.

Cohesion belongs particularly to solids, and is in fact the cause of their solidity. In some it is stronger than in others, rendering them harder or more tenacious. Liquids have so little cohesion that their weight alone overcomes it, and causes a separation of particles. In aëriform fluids cohesion is entirely wanting, its place being supplied by a Repulsive Force, which tends to make their particles spread out from each other.

34. Adhesion.—Adhesion is that property by which the surfaces of two different bodies placed in contact cling together.

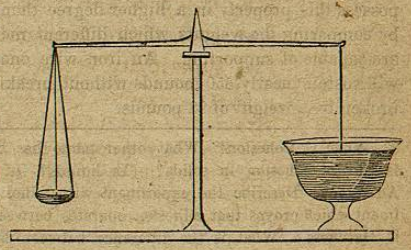
The bodies in question may be of the same kind of matter. This is proved by an experiment with two glass plates ground perfectly even. Let these be pressed together, and it will be found, on attempting to pull them apart by their handles, that considerable force will be required. The larger the surfaces of the plates, the harder it will be to separate them. A pair of Adhesion Plates is represented in Fig. 10.

Fig. 10.



ADHESION PLATES.

Fig. 11.



Adhesion also operates between the surfaces of solids and liquids. Suspend a piece of copper-plate from one side of a pair of scales, in such a way that its under surface may be parallel to the floor, and balance it with weights placed in the scale on the other side. Then, without disturbing the cop-

pressed and expanded? 31. What is Mobility? 32. What is Gravitation? How does it operate in the case of a cannon ball dropped from the hand to the earth? How does it operate in the case of two cannon-balls suspended close to each other?

per, place a vessel beneath it, as in Fig. 11, and pour in water till the liquid just reaches the plate. The adhesion between the solid and the liquid is now so strong that additional weights (more or less, according to the extent of surface) may be put in the scale on the other side without causing them to separate.

35. HARDNESS.—Hardness is that property by which a body resists any foreign substance that attempts to force a passage between its particles.

The hardness of a body depends on the degree of firmness with which its particles cohere. It is therefore entirely distinct from density, which depends on the number of particles in a given bulk. Thus lead is *dense*, but not *hard*.

Neither liquids nor aëriform fluids possess this property; and even in some solids, for instance butter and wax, it is almost entirely wanting.

Of two bodies, that is the harder which will scratch the surface of the other. By trying the experiment with different substances, it is found that the precious stones are harder than any other class of bodies, the diamond standing first, and the ruby, sapphire, topaz, and emerald following in order. Rhodium and iridium are among the hardest metals, on which account they are used for the tips of gold pens.

36. TENACITY.—Tenacity is that property by which a body resists a force that tends to pull it into pieces.

Both hardness and tenacity are the result of cohesion; but they must not be confounded. Of several rods equally thick, that which will support the greatest weight without breaking is the *most tenacious*; that which it is most difficult to cut into, is the *hardest*.

The metals generally are remarkable for their tenacity. Some, however, possess this property in a higher degree than others. This may be shown by comparing the weights which different metallic wires of the same size are capable of supporting. An iron wire one-tenth of an inch in diameter will sustain nearly 550 pounds without breaking, while one of lead will be broken by a weight of 28 pounds.

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33. What is Cohesion? What other name has been given to cohesion? What is said of cohesion in solids? In liquids? In aëriform fluids? 34. What is Adhesion? Describe the experiment with adhesion plates. Describe the experiment which proves that adhesion operates between solids and liquids. 35. What is Hardness? What is the difference between hardness and density? In what is hardness wanting? How may it be determined which of two bodies is the harder? What bodies are the hardest as a class? Mention the order in which they rank. What two metals are distinguished for their hardness? 36. What is Tenacity? Of what are both hardness and tenacity the result? Show the differ-

Iron is the most tenacious of the metals. A cable of this material, composed of wires one-thirtieth of an inch across, will support the enormous weight of 60 tons for each square inch in its transverse section. In consequence of this great tenacity, such cables are used for the support of suspension bridges.

37. *Tenacity of Different Substances.*—It is important in building and other arts to know the relative tenacity of different woods and metals. To determine this, experiments have been made. Their results do not precisely agree, inasmuch as there are differences in different trees of the same kind and different pieces of the same metal; yet we may take the following as the average weights that can be supported by the several materials mentioned,—taking in each case a rod of given length with a transverse section of a square inch.

		POUNDS.			POUNDS.
Metals.—	Cast Steel,	134,250	*Woods.*—	Ash,	14,000
	Swedish Iron,	72,000		Teak,	13,000
	English Iron,	55,800		Oak,	12,000
	Cast Iron,	19,000		Fir,	11,000
	Cast Copper,	19,000		Maple,	8,000
	Cast Tin,	4,700		*Rope*, one inch around,	1,000
	Cast Lead,	1,825		*Rope*, three inches around,	5,600

It is a curious fact that a composition of two metals may be more tenacious than either of them separately. Thus brass, which is made of zinc and copper, has more tenacity than either of those metals.

38. The liquids have comparatively little tenacity, yet there is a difference in them in this respect. Milk, for instance, is more tenacious than water; this makes it boil over more readily, inasmuch as its bubbles do not break, but accumulate, climbing one upon another till they overtop the vessel. In like manner, it is on account of their superior tenacity that soap-suds will make a lather while pure water will not.

39. BRITTLENESS.—Brittleness is that property which renders a body capable of being easily broken.

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ence between them. What is said of the tenacity of the metals? How may their relative tenacity be shown? Compare iron and lead in this respect. What is said of the tenacity of iron? 37. Explain the fact that experiments for determining the tenacity of different substances show different results. What does the table show? Of the metals mentioned in the table, which has the greatest tenacity? Which, the least? Of the woods mentioned, which is the most tenacious? Which, the least? What curious fact is mentioned respecting a composition of two metals? 38. What is said of the tenacity of liquids? How do milk and water compare in tenacity?

Brittleness is the opposite of tenacity, but often characterizes hard bodies. Glass, which is so hard that it will scratch the surface of polished steel, is remarkable for its brittleness.

A substance naturally tenacious may be so treated as to become brittle. Thus a bar of iron raised to a high degree of heat, if allowed to cool gradually, retains its tenacity, and bends rather than breaks; but, if suddenly cooled by being plunged into cold water, it is made brittle.

40. Elasticity.—Elasticity is that property by which a body, compressed, dilated, or bent by an external force, resumes its form when that force has ceased to act.

Stretch a piece of india rubber; when you let go the ends, they will fly back. Bend a bow; when the string is released, the bow will at once return to its former curve. These are familiar examples of elasticity.

41. The force with which a body resumes its form is called the Force of Restitution. Those bodies whose force of restitution brings them back, under all circumstances, exactly to their original form, are said to be *perfectly elastic.* The only perfectly elastic substances are the aëriform bodies. A body of air may be kept compressed for years; yet, on being freed from the compressing force, it will immediately expand to its former dimensions.

42. Many of the hard and dense solids are highly elastic; for example, steel, marble, and ivory. The soft solids generally, such as butter, putty, &c., have little or no elasticity; there are a few, however, that exhibit it, among which are india rubber and silk thread.

43. The elasticity of steel is increased by making it suddenly contract when expanded by heat. This is called *tempering*, and is effected by raising the steel to an intense heat, plunging it in cold water, and keeping it there for a certain time. The process is a nice one. At Damascus, in Syria, and Toledo, in Spain, it was long performed with peculiar skill, so that the sword-blades of those two cities were considered superior to all others. At the World's Fair in London, a Toledo sword was exhibited, of such exquisite temper that it could be bent into a circle, yet on being released sprung back and became as straight as ever.

44. A compound of two metals may possess a higher degree of elasticity

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Soap-suds and water? 39. What is Brittleness? Of what is brittleness the opposite? What is said of glass? How may iron be made brittle? 40. What is Elasticity? Give some familiar examples. 41. What is meant by the Force of Restitution? When is a body said to be perfectly elastic? What are the only perfectly elastic substances? 42. What solids are for the most part elastic, and what not? 43. How is the elasticity of steel increased? What is this process called? Describe the process of tempering. Where was it long done with peculiar skill? Give an account of the Toledo blade exhibited at the World's Fair. 44. What is said of a compound of two

than either of them separately. Thus bell-metal is much more elastic than either the tin or the copper of which it is composed.

45. An elastic body, thrown against any hard substance, rebounds. An india rubber ball bounds back from a wall, to a distance proportioned to the force with which it is thrown. In such cases, the ball is flattened at the point of contact, but instantly resumes its former shape with such force as to drive the ball back.

To prove this, take two ivory balls (Fig. 12), smear one of them with printer's ink, and suspend them near each other by strings of equal length. Bring them gently in contact, and a few particles of ink will adhere to the surface of the clean ball: strike them violently together, and a larger spot of ink will be found there. This could not happen if the two balls were not flattened at the moment of striking.

Fig. 12.

46. There is a limit to the elasticity of most bodies, beyond which, if compressed, dilated, or bent, they will fail to regain their original form. An iron wire, if slightly bent, springs back, so that no change of form can be detected; but not so, if violently bent. A continued application of the compressing, dilating, or bending force, has the same effect. A bow, if kept bent for a long time, will lose its elasticity. For this reason, an archer, before putting his bow away, is careful to unstring it.

47. The liquids have but little elasticity. They are therefore called Non-elastic Fluids; while aëriform bodies, which possess this property in a higher degree than any others, are known as Elastic Fluids.

48. Malleability.—Malleability is that property which renders a body capable of being rolled out or hammered into sheets.

From a piece of copper, a workman with no other instrument than his hammer will make a hollow vessel without joint or seam, the malleability of the metal preventing it from giving way under his blows. Dough, which can be made into very thin sheets under the rolling-pin, affords a familiar illustration of malleability.

Malleability belongs chiefly to the metals, yet in some of them, such as antimony and bismuth, it is wanting. It is strikingly exhibited in silver,

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metals? Give an example. 45. What does an elastic body do, when thrown against a hard substance? In such cases, what takes place? Prove this by an experiment. 46. What is said of the limit of elasticity? Give examples. 47. What names have been given to liquids and aëriform bodies? Why? 48. What is Malleability? Give

platinum, iron, and copper, but most of all in gold. A cubic inch of this metal may be beaten out till it covers 282,000 square inches, which makes the leaf only $\frac{1}{282000}$ of an inch thick. In other words, it would take 282,000 strips of such gold leaf, lying on each other, to make the thickness of an inch.

49. Ductility.—Ductility is that property which renders a body capable of being drawn out into wire.

The malleable metals are for the most part ductile, but not always in the same degree. Thus gold exceeds all the other metals in ductility as well as in malleability; but tin, which can readily be beaten into very thin sheets, can not be drawn out into small wire.

Gold wire has been made so attenuated that fifty miles of it would weigh but an ounce. Platinum, which is nearly as ductile as gold, has been drawn into wire only $\frac{1}{30000}$ of an inch in diameter and invisible to the naked eye. Glass, when softened by fire, becomes exceedingly ductile, and may be spun out into flexible and elastic threads scarcely larger than the thread of the silk-worm.

CHAPTER III.

MECHANICS.

50. Mechanics is that branch of Natural Philosophy which treats of forces and their application in machines.

51. Force and Resistance.—When we see a body begin to move, cease to move, or change its motion, since it can do neither of itself, we know that it has been acted on by some external agency, which we call a Force. The elasticity of a bow which sends an arrow through the air, is a force; the wind, which changes its direction, is a force; gravity, which brings it to the earth and helps to stop its motion, is a force.

examples. To what does malleability chiefly belong? Show the extreme malleability of gold. 49. What is Ductility? What substances are for the most part ductile? What is the most ductile substance known? What facts are stated, illustrating the ductility of gold, platinum, and glass?

50. What is Mechanics? 51. What is a Force? Give illustrations. What is the

That which opposes a force is called the Resistance. In the above example, the inertia of the arrow is the resistance.

Forces may act on bodies so as to produce either Motion or Rest.

Motion.

52. Motion is a change of place.

53. Motion is either Absolute or Relative.

Absolute Motion is a change of place with reference to a fixed point. Relative Motion is a change of place with reference to a point that is itself moving.

Two balls are rolled on the floor. The motion of each, as regards the point from which it was thrown, is absolute; their motion with reference to each other is relative.

54. Rest.—Rest is the opposite of motion, and implies continuance in the same place.

Like motion, Rest is either Absolute or Relative. A man sitting on a steamer that is moving forward five feet in a second, is at rest *relatively* to the other objects on board. To be at rest *absolutely*, he must walk five feet every second towards the stern of the boat.

Strictly speaking, there is no such thing as absolute rest in any of the objects that surround us; for the earth moves round the sun at the rate of nearly 99,000 feet in a second, and carries with it every thing on its surface. Hills, trees, and houses, therefore, though they occupy the same place with respect to each other, are really travelling through space with immense rapidity. Yet as this is the case with ourselves, with the atmosphere, and all things about us, we regard an object as absolutely at rest if it has no other motion than this.

55. Velocity.—The Velocity of a body is the rate at which it moves.

This rate is determined by the space it passes over in a given time. The greater the space, the greater the velocity. Thus, if A walks two miles an hour, and B four, B's velocity is twice as great as A's.

Resistance? What may the action of forces on bodies produce? 52. What is Motion? 53. How is motion distinguished? What is Absolute Motion? What is Relative Motion? Illustrate these definitions. 54. What is Rest? Illustrate Absolute and Relative Rest. Show that there is really no such thing as absolute rest. 55. What is