CHAPTER IX.

MECHANICS (CONTINUED).

WHEELWORK.—CLOCK AND WATCHWORK.

267. All machines, however complicated, are combinations of the six simple mechanical powers described in the last chapter. The chief objects in combining them are to gain a sufficient degree of power, and to give such a direction to the motion as will make the machinery do the work required.

Wheelwork.

268. The wheel enters more largely into machinery than any other of the Mechanical Powers.

269. Several wheels combined in one machine are called a Train.

270. In a train of two wheels, the one that imparts the motion is called the Driver; the one that receives it, the Follower.

271. Modes of Connection.—There are three ways in which motion may be transmitted from one wheel to another:—1. By the friction of their circumferences. 2. By a band. 3. By teeth on their outer rim.

272. *Friction of the Circumferences.*—One wheel may move another by rubbing on its circumference, or outer rim. The wheels are so placed that their rims touch, and one of them is set in motion. The circumference of each

267. Of what are all machines combinations? What are the chief objects in combining them? 268. Which of the mechanical powers enters most largely into machinery? 269. What is meant by a Train of wheels? 270. In a train of two wheels, which is the Driver? Which, the Follower? 271. In how many ways may motion be transmitted from one wheel to another? Mention them. 272. How may one wheel be made to move another by rubbing on its circumference? What is the ad-

having been previously roughened, friction prevents the moving wheel from slipping over the one at rest, and motion is imparted to the latter. Wheels thus connected work regularly and with little noise, but will not answer when a great resistance is to be overcome, and hence are not much used.

273. *Bands.*—One wheel may be made to move another by means of a band passed round both circumferences. Such a band is known as a Wrapping Connector. It is also called an Endless Band, because, its ends being joined, we never seem to reach them, though the motion is continuous in the same direction. The band must be stretched so tight that its friction on the wheels may be greater than the resistance to be overcome.

Fig. 126.

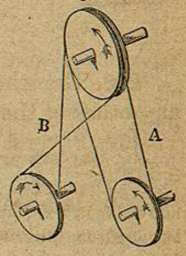
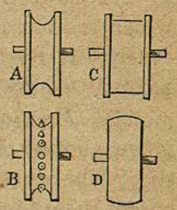


Fig. 126 shows how wheels are connected by an endless band. If the follower is to turn in the same direction as the driver, the band is passed over it without crossing, as in A; if in the opposite direction, the band is crossed, as in B.

274. The bands used for this purpose are generally made of leather, or gutta percha [*pert'-sha*]. The wheels may be far apart, if necessary; and on this account, as well as because a great amount of power may thus be transmitted, the wrapping connector is much used. The motion imparted is exceedingly regular, any little inequalities being corrected by the stretching of the band.

Fig. 127.



275. Fig. 127 shows the different forms given to the circumferences of wheels, in order that the band may not slip off. A's circumference is concave, or hollows towards the centre, with a rim on each side. B's is the same, with a row of pins down the centre. C's circumference is even across, with a rim on each side. D has no rim, but bulges out in the centre, so that when the band tends to approach one side it is pulled back by the tightening on the other.

vantage, and what the disadvantage, of this mode of connection? 273. What is a Wrapping Connector? What other name is given to it, and why? How tight must the band be? In passing from the driver to the follower, when is the band crossed, and when not? 274. Of what are endless bands usually made? By what advantages is their use attended? What renders the motion imparted by wrapping connectors exceedingly regular? 275. Describe the different forms given to the circumferences of wheels on which a wrapping connector is to act. 276. What is the third way in

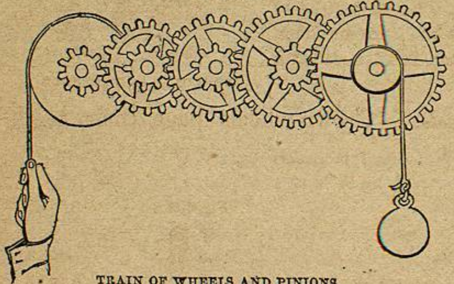
Fig. 128.

276. *Teeth.*—One wheel may be made to move another by means of teeth on the circumference of each. A toothed wheel is shown in Fig. 128.

277. Small toothed wheels combined with large ones are called Pinions, and their teeth Leaves.

278. Two or more wheels connected by teeth are called Gearing. When so arranged that the teeth work in each other, they are said to be *in gear;* and when not, *out of gear.*

Fig. 129.



TRAIN OF WHEELS AND PINIONS.

Figure 129 shows a train of wheels and pinions in gear. To find how great a weight will be balanced by a given power with such a train, multiply the power successively by the number of teeth on the wheels, and divide by the product of the number of teeth on the pinions. For instance, in Fig. 129, let the first large wheel have 18 teeth, the second 18, the third 27, and the fourth 27; and let each pinion have 9 teeth. Then (leaving friction out of account) a power of 2 pounds will balance a weight of 72 pounds. For

$$2 \times 18 \times 18 \times 27 \times 27 = 472392$$
$$9 \times 9 \times 9 \times 9 = 6561$$
$$472392 \text{ divided by } 6561 = 72$$

279. Kinds of Toothed Wheels. — There are three kinds of toothed wheels; viz., Spur-wheels, Crown-wheels, and Bevel-wheels.

280. *Spur-wheels.*—Spur-wheels have their teeth perpendicular to their axes, as shown in Fig. 129.

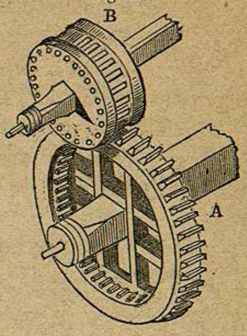
The teeth are either made in one piece with the rim, or

which one wheel may be made to move another? 277. What are Pinions? What are the teeth of pinions called? 278. What is Gearing? When are wheels said to be *in gear?* When are they said to be *out of gear?* What does Fig. 129 represent? With such a train, how do you find how great a weight will be balanced by a given power? Give an example. 279. How many kinds of toothed wheels are there? Name them. 280. Describe Spur-wheels. How are the teeth made? What are

consist of separate pieces set into the rim. In the latter case, they are called Cogs.

In mills, Cog-wheels are generally used with Trundles, or Lanterns, as represented in Fig. 130.

Fig. 130.



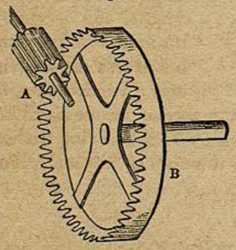
COG-WHEEL AND TRUNDLE.

A is a large cog-wheel. B is a trundle, consisting of two parallel discs and an intervening space traversed by round pins called Staves, so arranged as to receive the cogs of the other wheel.

Mill-wheels are generally made of cast-iron; but they are found to work most smoothly when one of them has wooden instead of iron teeth. Wooden teeth are therefore often set in the larger one, which is then called a Mortice-wheel.

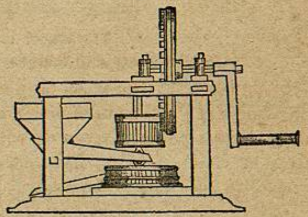
281. *Crown-wheels.*—Crown-wheels have their teeth parallel to their axes.

Fig. 131.



CROWN-WHEEL AND PINION.

Fig. 132.



HAND-MILL.

Fig. 131 represents the contrate-wheel and pinion of a watch. B, whose teeth run the same way as its axis, is a crown-wheel. A, whose teeth are at right angles to its axis, is a spur-wheel.

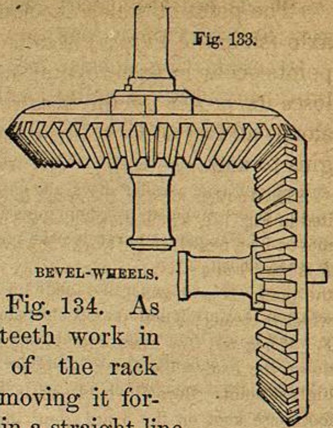
Fig. 132 shows how a crown-wheel worked by a winch is combined with a trundle in a hand-mill used in Germany and Northern Europe. The crown-wheel moves vertically, but it communicates a horizontal motion to the trundle, which in turn imparts it to the mill-stone.

282. *Bevel-wheels.*—Bevel-wheels are wheels whose teeth

Cogs? In mills, with what are cog-wheels generally used? Describe a Trundle Of what are mill-wheels generally made? What is said of their Teeth? What is a Mortice-wheel? 281. Describe Crown-wheels. What does Fig. 131 represent? Describe the hand-mill represented in Fig. 132. 282. What are Bevel-wheels? What form any other angle with their axes than a right angle.

A pair of bevel-wheels in gear are shown in Fig. 133.

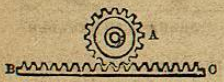
Fig. 133.



BEVEL-WHEELS.

283. Rack and Pinion.—Circular motion is converted into rectilinear (that is, motion in a straight line) by means of the rack and pinion, represented in Fig. 134. As the pinion A revolves, its teeth work in those of the rack B C, moving it forward in a straight line.

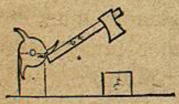
Fig. 134.



RACK AND PINION.

284. Forge-Hammer.—A toothed wheel may produce an alternate up-and-down motion, as in the case of the Forge-hammer, represented in Fig. 135.

Fig. 135.

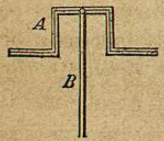


THE FORGE-HAMMER.

The wheel is so placed that its teeth successively come in contact with the handle of the hammer, which turns on a pivot. As the wheel revolves, a long tooth carries the lower end of the handle down and raises its head. As soon as the tooth releases the handle, the head of the hammer falls on the anvil by its own weight. A new tooth then comes into play, and the operation is repeated.

285. Cranks.—The Crank is much used in machinery for converting circular motion into rectilinear, or rectilinear into circular. It has different forms, but is generally made by bending the axle in the way represented in Fig. 136. As the wheel to which it is attached turns, the crank A also revolves, and causes the rod B, with which it is connected, to move alternately up and down.

Fig. 136.

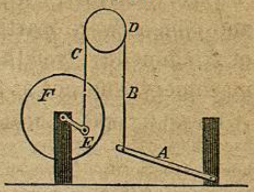


THE CRANK.

does Fig. 133 represent? 283. How may circular motion be converted into rectilinear? Describe the working of the Rack and Pinion. 284. What kind of motion does a toothed wheel produce in the case of the forge-hammer? Explain the working of the forge-hammer. 285. For what is the Crank used? Describe its usual form, and

The point at which the rod stands at right angles to the axle (as in the Figure) is called the Dead-point. Two dead-points occur in each revolution. When at either, the crank loses its power for the instant; but the impetus carries it along, and as soon as the dead-point is passed it again begins to act.

Fig. 137.



CRANK AND TREADLE.

286. Another form of the crank is exhibited in Fig. 137, which shows how a wheel is moved by a treadle-board worked by the foot. A is the treadle; B C is a cord passed round the pulley D, and attached to the crank E, which is connected with the axle of the wheel F. When the foot bears the treadle-board down, the end of the crank is raised to its highest point. Here it would remain if the foot were kept on the board; but, the foot being removed, the impetus of the wheel carries the crank round again to its lowest point, raising in turn the end of the treadle-board. The foot is now applied again with the same effect as before, and continuous motion is thus imparted to the wheel.

287. Fly-wheels.—The motion of machinery must be even and regular. Both power and resistance must therefore act uniformly; if either increases too rapidly, the sudden strain is apt to break some part of the works. To prevent this, the fly-wheel is used.

The fly-wheel appears in various forms, but generally consists of a heavy iron hoop with bars meeting in the centre. It is set in motion by the machinery, and by reason of its weight acquires so great a momentum that irregularities either in power or resistance, unless long continued, have but little effect. If, for instance, the power ceases to act for a moment, or the resistance suddenly increases or diminishes, the great momentum of the fly prevents the motion of the machinery from varying to any great extent.

288. The fly-wheel also accumulates power, and thus enables a machine to overcome a greater resistance than it could otherwise do. The power,

explain its operation. What is meant by the Dead-point of the crank? What is said of the crank at its dead-point? 286. What does Fig. 137 represent? Explain the operation of the crank and treadle. 287. For what is the Fly-wheel used? Of what does it generally consist? Explain how the fly-wheel prevents irregularities of motion. 288. For what other purpose is the fly-wheel used? How does the fly-wheel allowed to act on the fly alone for a short time, gives it an immense momentum; and this momentum directly aids the power, when the machine is applied to the required work.

Clock and Watch Work.

289. One of the commonest and most ingenious applications of wheelwork is exhibited in clocks and watches.

290. History.—The advantages of combining wheels and pinions were partially known as far back as the time of Archimedes; yet they were comparatively little used in machinery, and not at all for the measurement of time.

Instead of clocks and watches, consisting of trains of wheels, the ancients used the sun-dial, and clep′-sy-dra or water-clock. The former indicated the hour by the position of the shadow cast by a style, or pin, on a metallic plate; the latter, by the flow of water from a vessel with a small hole in the bottom. The dial was of course useless at night; and neither it nor the clepsydra, however carefully regulated, could measure time with any great degree of accuracy.

Even Alfred the Great, 985 years after Christ, had no suitable instrument for measuring time. To tell the passing hours, he used wax candles twelve inches long and of uniform thickness, six of which lasted about a day. Marks on the surface at equal intervals denoted hours and their subdivisions, each inch of candle that burned showing that about twenty minutes had passed. To prevent currents of air from making his candles burn irregularly, he enclosed them in cases of thin, transparent horn,—and hence the origin of the lantern.

291. Clocks moved by weights were known to the Saracens as early as the eleventh century. The first made in England (about 1288 A. D.) was considered so great a work that a high dignitary was appointed to take care of it, and paid for so doing from the public treasury. The usefulness of clocks was greatly increased by the application of the pendulum, which was made about the middle of the seventeenth century.

Watches seem to have been first made in the six-

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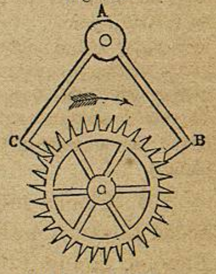
aid the power? 289. In what do we find one of the most ingenious applications of wheel-work? 290. What is said of the knowledge of wheel-work possessed by the ancients? What did the ancients use for the measurement of time? How did the sun-dial indicate the hour? How, the clepsydra? What is said of the accuracy of these instruments? How did Alfred the Great measure time? What was the origin of the lantern? 291. When were clocks moved by weights first made by the Saracens? When was the first made in England? How was this clock regarded? What

teenth century, though it is not known who was their inventor. For a time they were quite imperfect, requiring to be wound twice a day, and having neither second nor minute hand. The addition of the hair-spring to the balance, by Dr. Hooke, in 1658, was the first great improvement. Others have since been devised; and chronometers (as the best watches, manufactured for astronomers and navigators, are called) are now made so perfect as not to deviate a minute in six months, even when exposed to great variations of temperature.

292. Clock-work.—In clocks, except such as are moved by springs similarly to watches, the moving power is a weight; to which, when wound up, gravity gives a constant downward tendency. In its effort to descend, it sets in motion a train of wheels and pinions; and they move the hands which indicate the hours and minutes on the face.

Fig. 138.



THE ESCAPEMENT.

The motion of the wheels, though caused by the weight, is regulated by the pendulum and an apparatus called the Escapement, shown in Fig. 138. The *crutch* A B C moves with the pendulum. As the latter vibrates, the *pallets* B, C, are alternately raised far enough to let one tooth of the *scape-wheel* pass, its motion at other times being checked by the entrance of one of the pallets between the teeth. Hence, though the weight is wound up, the clock does not go till the pendulum is set in motion. If the pendulum and escapement are removed, the weight runs down unchecked, turning the various wheels with great rapidity. The motion of the wheels is thus made uniform by the pendulum; and by shortening or lengthening it we can make the clock go faster or slower.

293. Watch-work.—In a watch, there is no room for a weight or pendulum; hence a spring, called the *main-*

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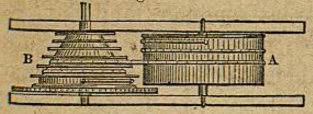
greatly increased the usefulness of clocks? When were watches first made? What was the character of those first constructed? What was the first great improvement? What is said of the chronometers made at the present day? 292. What is the moving power in clocks? How does the weight set the clock in motion? How is the motion of the wheels regulated? Explain, with Fig. 138, how the Escapement regulates the motion. If the pendulum and escapement are removed, what is the consequence? How is the clock made to go faster or slower? 293. In a watch, what *spring*, is substituted for the former as a moving power, while the *balance* and *hair-spring* take the place of the latter as a regulator.

The main-spring is either fixed to an axle capable of revolving, as shown at O P in Fig. 140, or is contained within a hollow barrel, connected by a chain with a conical axle, called the *fusee*, represented in Fig. 139. A is the barrel, within which and out of sight is the main-spring, having one end attached to the inner surface of the barrel, and the other fastened to a fixed axle passing through the barrel. B is the fusee.

Fig. 139.



THE FUSEE.

The watch is wound up with a key, applied to the square projecting from the fusee. By turning the square the chain is drawn off from the barrel and wound round the fusee. The barrel is thus turned till the spring in the inside is tightly coiled. This spring, by reason of its elasticity, tends to uncoil, and in so doing moves the barrel round, drawing off the chain from the fusee, and winding it again around the barrel. The fusee is thus turned, and carries with it the first wheel of the train, which imparts motion to all the rest. When the spring has uncoiled itself, the chain, being entirely wound round the barrel, ceases to move the fusee, and all the wheels come to rest. The watch is then said *to run down*.

The reason of the peculiar shape of the fusee is this. The power of the spring is proportioned to the tightness with which it is coiled, and hence is greatest when the watch is first wound. The chain is consequently then made to act on the smallest part of the fusee; because the nearer to the axis the force is applied, the less its power of producing motion. As the spring gradually uncoils, its power is weakened and it is made to act on a larger part of the fusee. By thus adjusting the size of the fusee to the varying power of the spring, a uniform effect is secured.

294. An escapement similar to that used in clocks connects the moving power with the balance. To the latter, also, a very fine spiral spring is attached, which is fastened at its other end to a fixed support. The watch is regulated by shortening or lengthening this spring, the balance being made to vibrate faster or slower accordingly.

295. The works of an ordinary watch are shown in Fig. 140. For convenience of inspection, they are arranged in a line, and the distance between the two plates, and also between the upper plate and the face, is increased.

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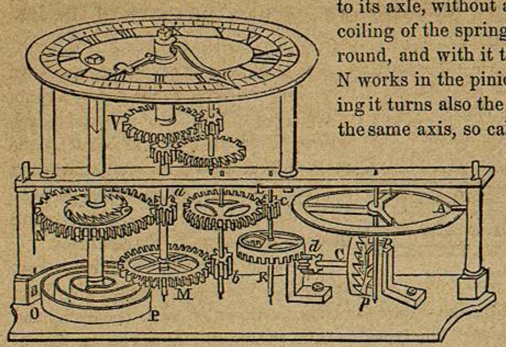
takes the place of the weight, and what of the pendulum? What two ways are there of fixing the main-spring? Explain Fig. 139. How is the watch wound up? Explain the working of the fusee. When does the watch run down, and why does motion then cease? What is the reason of the peculiar shape of the fusee? 294. What connects the moving power with the balance? What is attached to the balance? How

Fig. 140.



WORKS OF A WATCH.

O P is the *main-spring*, attached to its axle, without a fusee. The uncoiling of the spring carries the axle round, and with it the *great wheel* N. N works in the pinion *a*, and by turning it turns also the *centre-wheel* M on the same axis, so called from being in the centre of the watch. M turns the pinion *b* and the *third wheel* L, which in turn works in the pinion *c* and causes the *second* or *contrate-wheel* R, on the same axis, to revolve. R works in the pinion *d* and carries round the *balance* or *crown wheel* C, which is on the same axis with it.

The saw-like teeth of the balance-wheel are checked (as in the case of the escapement of a clock) by the *pallets p, p*, which are projecting pins on the *verge* of the *balance* A. The *hair-spring*, fastened at one end to a fixed support, and at the other to the balance, may be shortened by the *curb* or *regulator*, if the watch goes too slow, or lengthened if it goes too fast, thus controlling the motion of the balance and consequently that of the other wheels.

296. The force of the main-spring is so adjusted as to make the great wheel N revolve once in four hours. The spring generally turns it seven or eight times round before it is uncoiled, so that with one winding the watch runs twenty-eight or thirty-two hours. The great wheel N has forty-eight teeth, the pinion *a* but twelve; so that *a* and the centre-wheel M revolve once every hour, and their axle, carried through to the face, bears the minute-hand.

Between the face and the upper plate is a train of pinions and wheels connected with the axle of the centre-wheel. They are so adjusted that the wheel V revolves once in twelve hours. V carries the hour-hand. It is attached to a hollow axle, through which the axle of the centre-wheel passes to carry the minute-hand.

297. Thus we see that the works of a watch are nothing more than an ingenious combination of wheels, moved by a spring and regulated by a balance. The arrangement of the

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is the watch regulated? 295. What does Fig. 140 represent? With the aid of Fig. 140, describe the works of a watch and their mode of operation. How is the watch regulated? 296. How great a force is generally given to the main-spring? How long does the watch run with one winding? Explain the arrangement of the minute-hand. Explain that of the hour-hand. 297. Of what, as we have seen, do the works wheels and pinions is such, that there is a constant increase of velocity and a corresponding loss of power. The great wheel, which begins the train, revolves once in four hours; the balance, which closes it, revolves in one-fifth of a second; but the force of the spring becomes so attenuated by the time it reaches the balance, that the slightest additional resistance there, a particle of dust or even a thickening of the oil used to prevent friction, deranges, and may stop, the action of the whole.

CHAPTER X.

MECHANICS (CONTINUED).

HYDROSTATICS.

298. HYDROSTATICS and Hydraulics are branches of Mechanics that treat of liquids.

Hydrostatics is the science that treats of liquids at rest.

Hydraulics is the science that treats of liquids in motion, and the machines in which they are applied.

299. The principles of Hydrostatics and Hydraulics are equally true of all liquids; but it is in water, which is the commonest liquid, that we most frequently see them exhibited.

Water abounds on the earth's surface. It covers more than two-thirds of the globe, and constitutes three-fourths of the substance of plants and animals.

300. NATURE OF LIQUIDS.—Liquids differ from solids in having but little cohesion.

of a watch consist? What is said of the arrangement of the wheels and pinions? What is the comparative velocity of the great wheel and the balance? What is said of the force of the spring by the time it reaches the balance?

298. What sciences treat of liquids? What is Hydrostatics? What is Hydraulics? 299. What is said of the principles of hydrostatics and hydraulics? How much of the globe is covered with water? How much of the substance of plants and animals consists of water? 300. In what respect do liquids differ from solids? What shows

Cohesion is not entirely wanting in liquids, as is proved by their particles' forming in drops; but it is so weak as to be easily overcome. Thick and sticky liquids, like oil and molasses, have a greater degree of cohesion than thin ones, like water and alcohol.

301. Liquids were long thought to be incompressible, but experiment has proved the reverse. Submitted to a pressure of 15,000 pounds to the square inch, a liquid loses one-twenty-fourth of its bulk. Were the ocean at any point a hundred miles deep, the pressure of the water above on that at the bottom would reduce it to less than half its proper volume.

302. To distinguish them from the gases, liquids are often called non-elastic fluids; yet they are not devoid of elasticity.

To prove this, after compressing a body of water, remove the pressure, and it will resume its former bulk. Again, if a knife-blade be brought in contact with a drop of water hanging from a surface, the drop may be elongated by slowly drawing away the blade; but it immediately returns to its original shape, if the blade is entirely removed without detaching the drop from the surface.

Law of Hydrostatics.

303. *Water at rest always finds its level.*

No matter what the size or shape of a body of water may be, its surface has the same level throughout; that is, it is equally distant at every point from the earth's centre. Accordingly, the surface of the ocean is spherical; and this we know to be the case from always seeing the mast of a vessel approaching in the distance before we see the hull. In small masses of liquids, no convexity is perceptible; and we may consider their surfaces as perfectly flat.

304. The tea-pot affords us a familiar illustration of this law. The tea always rises as high in the spout as in the body of the pot; and, if the body is higher than the spout, it will pour out from the latter when the pot is filled.

So, let there be a number of vessels having communication at their bases, as shown in Fig. 141. If water be poured into any of them, it will rise to

that cohesion is not entirely wanting in liquids? What liquids have the most cohesion? 301. What is said respecting the compressibility of liquids? If the ocean were a hundred miles deep, what would be the consequence of the pressure? 302. What are liquids often called, to distinguish them from gases? Is the name strictly correct? Prove that liquids are elastic? 303. What is the great law of Hydrostatics? What do we mean, when we say that a body of water has the same level throughout? What sort of a surface must the ocean have? What evidence is there of this? How may we regard the surfaces of small bodies of liquids? 304. Show how the tea-pot illus-