SCIENCE FOR THE YOUNG

HEAT

BY JACOB ABBOTT

J. Abbott

SCIENCE FOR THE YOUNG;

OR,

THE FUNDAMENTAL PRINCIPLES OF MODERN PHILOSOPHY EXPLAINED AND ILLUSTRATED

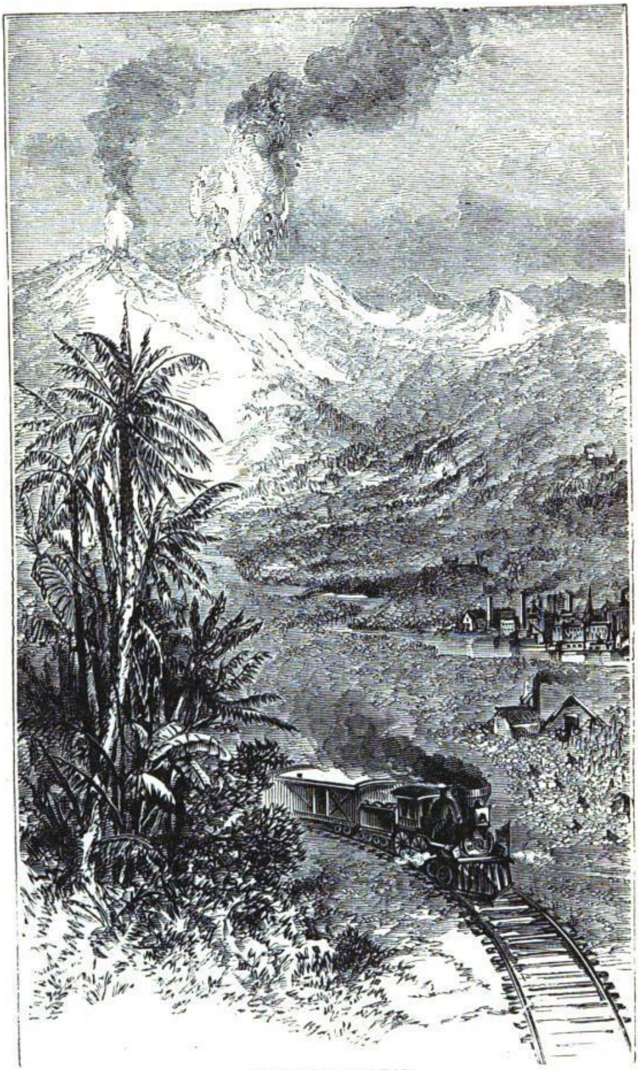
IN

CONVERSATIONS AND EXPERIMENTS,

AND IN

NARRATIVES OF TRAVEL AND ADVENTURE BY YOUNG PERSONS IN PURSUIT OF KNOWLEDGE.

VOL. I.—HEAT.



THE DOINGS OF HEAT.

SCIENCE FOR THE YOUNG.

HEAT.

BY JACOB ABBOTT,

AUTHOR OF

"THE FRANCONIA STORIES," "MARCO PAUL SERIES," "YOUNG CHRISTIAN SERIES," "HARPER'S STORY BOOKS," "ABBOTT'S ILLUSTRATED HISTORIES," &c.

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OBJECT OF THE WORK.

The object of this series, though it has been prepared with special reference to the young, and is written to a considerable extent in a narrative form, is not mainly to amuse the readers with the interest of incident and adventure, nor even to entertain them with accounts of curious or wonderful phenomena, but to give to those who, though perhaps still young, have attained, in respect to their powers of observation and reflection, to a certain degree of development, some substantial and thorough instruction in respect to the fundamental principles of the sciences treated of in the several volumes. The pleasure, therefore, which the readers of these pages will derive from the perusal of them, so far as the object which the author has in view is attained, will be that of understanding principles which will be in some respects new to them, and which it will often require careful attention on their part fully to comprehend, and of perceiving subsequently by means of these principles the import and significance of phenomena occurring around them which had before been mysterious or unmeaning.

In the preparation of the volumes the author has been greatly indebted to the works of recent European, and especially French writers, both for the clear and succinct expositions they have given of the results of modern investigations and discoveries, and also for the designs and engravings with which they have illustrated them.

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CHAPTER I.

THE GREAT DEVOURER.

Lawrence and his cousin John were sitting at a table together in the breakfast-room of a large hotel in New York, waiting for their breakfast to be brought in. After breakfast the coach was to come which was to take them on board the steamer Scotia, in which they had taken passage for Europe. The steamer was to sail that day at eleven o'clock, and it was now about eight. The coach was expected at half past nine.

"I am glad we are going in an iron steamer instead of a wooden one," said John. "We are safe, at any rate, from being *burnt up* on our voyage, though we may get blown up."

"And yet," replied Lawrence, "iron is more combustible than wood."

"Oh, Lawrence!" exclaimed John.

John was only about thirteen years of age, but Lawrence was over twenty, and he had just completed his studies at a scientific school in New Haven. His head was, consequently, very full of scientific ideas, and his talk of scientific words.

"Perhaps I am wrong in saying exactly that," added Lawrence. "I am not sure that I know precisely what is implied by a thing's being *more* or *less* combustible. What I mean to say is that it is *more strictly and completely true* that iron is combustible, than to say that wood is."

"But, Lawrie," said John, "that can not possibly be so; for iron is not combustible at all. You can heat it *red hot* without its taking fire. Besides, if it is combustible, how is it that the tongs do not take fire when we take up burning coals with them, and how can they make andirons of it, and stoves, and grates? I'll bet you any thing that it is not combustible."

"What will you bet?" asked Lawrence.

"I'll bet you an orange," said John, "to pay when we get on board the ship."

"But we can have as many oranges as we want on board the ship, just for the asking," said Lawrence.

"Then I'll bet you a pound of grapes," said John, "when we get to Paris."

"Done," said Lawrence; "and whom shall we leave it to?"

Just at this moment the waiter appeared, bringing the breakfast. It consisted of coffee, hot rolls and butter, a beefsteak, and some boiled eggs. The boys paused in their conversation to watch the movements of the waiter in arranging these things upon the table. Their minds, too, were occupied in agreeable anticipations of the pleasure of having so good a breakfast.

It may seem rather disrespectful to Lawrence to designate him as a boy, but the major—a gentleman who was going to make the voyage with them, and who was a relative of theirs—having been accustomed to call Lawrence and John both boys when they were younger, still continued the practice, and I shall take the same liberty, on account of the convenience of it.

When the waiter had arranged every thing properly

BREAKFAST-ROOM AT THE HOTEL.

upon the table, he lifted the cover from the beefsteak and went away.

"We'll leave it to the major," said John.

"This is a nice steak," said Lawrence.

The steak did indeed look very nice, as it lay in the midst of its rich gravy upon the oval dish. Lawrence took up a knife and fork and began to divide it into two parts, in order to put one part upon a plate for John.

"On the whole," said he, after he had given John his portion of the steak, and had also poured him out a cup of coffee—"on the whole, I think we will give up the bet. It is not a good plan to make bets. I will explain to you how it is that iron is more strictly and completely combustible than wood, and then you can judge for yourself."

"Yes," replied John, "that will be better."

Just then, in looking up, John's eyes fell upon the figure of a boy a little younger than himself, who was standing at the door. As soon as he saw John looking at him, he began to make up laughable faces at him and perform various antics, without, however, making any noise, so that he did not attract the attention of any body else in the room.

"Ah!" said John, "there's Flippy."

"Flippy!" repeated Lawrence. "That's a funny name."

"Well, he's a funny fellow," said John, "and he ought to have a funny name."

"But what is his real name?" asked Lawrence. "Flippy is no name at all."

"I don't know what his real name is," said John. "They call him Flippy. And he is going with us across the Atlantic."

"That is good," said Lawrence; "for now you will have a playmate on board."

During this conversation John had beckoned to Flippy several times to come to them. Flippy had, however, taken no notice of this invitation, but still stood in the doorway. He was rather short and thick in form, but his countenance was frank and open, and it wore a good-natured and rather pleasing expression.

Lawrence thought at first that the reason why Flippy did not come, in compliance with John's beckoning, was that he was afraid. But he soon found that bashfulness was not the cause which kept him back, for, after waiting a moment, he suddenly walked in, apparently entirely at his ease, and came through the room to the table where Lawrence and John were sitting.

"I wish *my* breakfast was ready," said he. "I've got a devouring appetite."

"That's right," said Lawrence. "You had better have a good appetite now, for I'm afraid you will have very little after you've been at sea twenty-four hours. Do you think you could devour a large piece of beefsteak this morning?"

Flippy said he could; and then Lawrence asked him and John what they thought was the greatest devourer in the world.

"Is it a conundrum?" asked Flippy.

"No," said Lawrence, "it is a serious question."

"I wish it was a conundrum," said Flippy. "I can guess conundrums first-rate."

"No, it is not a conundrum," repeated Lawrence; "it is a serious question."

"The lion," said John, guessing.

"No," said Lawrence. "The lion is a great devourer, but not nearly so great as the one I am thinking of."

"Then it must be the tiger," said John.

"No," replied Lawrence, shaking his head.

"Then it must be the whale," said John. "Whales devour an enormous quantity of little fishes, and squids, and such things. They strain them out of the water when they spout. I read it in a book."

"No," replied Lawrence, "it is not the whale."

"I know what it is," said Flippy. "It is rats."

Lawrence laughed.

"Why, you see, the reason why the rats devour so much," said Flippy, looking very serious, "is because there are so many of them. There are more rats in the world than any thing else."

Lawrence said that Flippy had made a very good guess, for rats really were great devourers, and there were so many of them in the world, as Flippy said, that the amount that was eaten up by the whole race was enormous. But the devourer that he was thinking of beat the rats entirely. It consumed more than all the lions, tigers, whales, and rats a hundred times over. It was *oxygen.*

"What's that?" asked Flippy.

"It is something in the air," said Lawrence.

"Yes," said John. "I know about that. It is gas."

"It is gas while it is in the air," replied Lawrence, "but when it has devoured any thing it often becomes liquid or solid, in union with what it has devoured. There is more of it in the world than there is of any thing else. It forms about one quarter of the substance of the air, about one half of nearly all the rocks and earth, and nearly nine tenths of all the water in the rivers and in the sea. So you see, Flippy, that there is a greater amount of oxygen in the world than even of rats.

"But then," continued Lawrence, "it is only that portion of the oxygen which is in the air that acts as a devourer. All that is in the rocks and in the ground, and also all that which forms a part of the water of the rivers and of the sea, has got its fill with what it has already devoured, and wants no more. What is in the air is free and hungry. It is all the time on the watch for something to devour."

Here Flippy began to look a little weary. John, who had read and studied somewhat on these subjects, was quite interested in what Lawrence was saying, simply because he knew something about it already. He had read about oxygen, and had heard some lectures about it, and had seen the lecturer prepare some of it; that is, separate a portion of it from certain substances with which it was combined, so as to obtain some jars of it pure, and then burn phosphorus, and charcoal, and sulphur, and other combustibles in it, thus producing a very intense ignition and a very brilliant light. But he had never before heard how vast a portion of what exists in this world, whether air, or water, or land, consists of this substance, and still less had he ever heard that the land and sea are formed of substances with which oxygen is already combined, and that it lies quiet in them in consequence of being satisfied with the combination; while that which is in the air is free, and is all the time on the watch for something which it too could devour.

So John was very much interested in what Lawrence said. But Flippy, knowing nothing about oxygen at all, was not interested, and soon went away. If it had been about the devourings of lions, tigers, or rats, he too would have been interested, and would have remained, for he knew something about such devourers as those.

And this is an illustration of one of the great advantages of learning. When you know a little about any thing, that knowledge adds greatly to the pleasure and interest you take in learning more. If a man were to deliver a lecture on fishing to a company of boys, those would be most interested in the lecture who knew most about fishing before. If the lecture were upon electricity, those would like it best who had had electric machines themselves, and had learned something of the science by their own experiments. So a great many more people in this country are interested in reading books of travels in England than in France, because they know more about England than about France; and more are interested in reading about France than about India, because they know more about France than about India.

This is a great encouragement to us all to acquire knowledge by every means in our power, for we not only have the pleasure of knowing what we learn at the time, but we lay up for ourselves a future reward by adding to the zest, that is, the intensity, of the pleasure we shall derive from the additional knowledge on the same subject which we may acquire at any future time.

CHAPTER II.

LIFE, DEATH, AND DISSOLUTION.

"We boys prepared some oxygen ourselves once," said John. "We learned how to do it at the lecture, at school."

"How did you do it?" asked Lawrence.

"Why, we put the materials in a bottle," said John, "and put a pipe-stem through the cork, and then fitted an India-rubber tube to the top of the pipe-stem, and carried the end of the tube under a glass jar, which we held upside down in the water in a water-pail. Pretty soon the oxygen gas began to come over through the pipe and the tube, and bubbled up in the jar, until all the water in the jar was driven out, and it was filled with oxygen instead. Then we slid a plate under the mouth of the jar, and turned it right side up, and set it on the table. Only we kept the plate on it, to prevent the oxygen from coming out. You see the jar was full of oxygen gas, but it did not look like any thing at all. It looked just as if the jar was empty, or, at least, as if there was nothing in it but air."*

"How do you know there *was* any thing in it but air?" asked Lawrence.

"Oh, we burned some things in it," replied John, "and

* The opposite cut illustrates an apparatus for producing oxygen. It consists of a stand, with rests to support a spirit-lamp and a glass retort; a tank for holding water, and jars for collecting oxygen. Into the retort, which holds a pint, are placed three ounces of chlorate of potassia and an ounce of peroxide of manganese; the beak of the retort is placed under water in the tank, just below the mouth of an inverted jar, which rests on a shelf. The lamp is then lighted, and the oxygen, disengaged, rises through the water into the jar.

they burned a *great deal* brighter than they would in the air."

"The oxygen devoured them very eagerly," said Lawrence.

"Only we broke our jar," said John. "We had a little bit of phosphorus that the professor gave us. We kept it in a little phial in water—for it will take fire and burn of itself if it comes to the air."

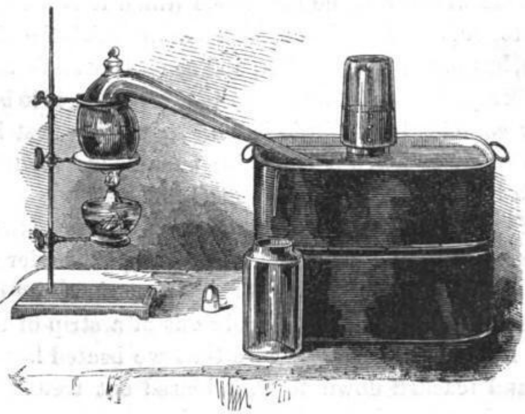
"Yes," replied Lawrence; "oxygen has a tremendously voracious appetite for phosphorus. It will seize upon it furiously wherever it can get at it. The only means of keeping it out of the oxygen's way is to keep it under water."

"Yes, but there is one thing that I don't understand," said John. "Water itself is about nine tenths oxygen."

"It is nearer eight ninths," said Lawrence.

"You said nine tenths, I thought," rejoined John. "*Nine tenths* of the water, *one quarter* of the air, and *one half* the rocks and the ground."

"I am glad you remember so well," said Lawrence. "I



PRODUCING OXYGEN.

said *about* nine tenths, as I only meant to give you a general idea how large a proportion of water is composed of oxygen. It is really about eight ninths. That is, there are eight parts of oxygen to one of hydrogen."

"Well, no matter about the exact proportion," said John. "At any rate, there is a great deal. In fact, water is nearly all oxygen. Now, if oxygen is so voracious after phosphorus, how can it be kept under water any better than in the air? Why doesn't the oxygen that is in the water attack it and devour it?"

"Because the oxygen that is in the water," replied Lawrence, "has its appetite satisfied by the hydrogen which it has already devoured; while that which is in the air is free, or, at least, comparatively free, and so is still hungry."

"Or, in other words," continued Lawrence, "to give up representing the oxygen as a wild beast, and to talk plain English about it, the oxygen in water is already combined with hydrogen, for which it has a prodigiously strong affinity, and all its force is expended and neutralized. It will not leave the hydrogen for the sake of the phosphorus. Whereas in the air, the substance which it is united with is nitrogen, and it is either not *combined* with the nitrogen at all, but only mixed with it, and so each particle is in full and free possession of all its native force—or, if it is chemically combined with it, it is held so weakly that it is always ready to leave it and seize upon the phosphorus, for which it has a very much stronger affinity."

"Yes," said John, "I see. Well, at any rate, the phosphorus remained quiet as long as we kept it under water; but when we took it out, and let it down into the oxygen in a kind of spoon that we made out of a strip of tin, and then set it on fire with a wire that we heated hot at one end and reached down to it, it blazed out tremendously, and made such a bright light that it dazzled us to look at it, till it was hid by the white smoke; and by-and-by some drops fell down into the bottom of the jar and broke it, and all the white smoke came out into the room. As soon as the jar cracked, the boys all ran off toward the door. They thought they were going to be blown up."

Here John laughed at the recollection of the panic which was occasioned among the boys at the close of their experiment.

"Then you know something about oxygen, it seems," said Lawrence—"at least about its nature and action on a small scale."

"Yes," replied John; "but I did not know any thing about there being such enormous quantities of it in the world."

Lawrence was perfectly correct in his statements. The quantity of oxygen in the world is really enormous, forming, as it would seem, more than one half of all that portion of the material world which comes under our observation. How far this abundance of oxygen may extend into the interior of the earth we do not know. But in the atmosphere, in the water of the sea and of the rivers, and in all that portion of the solid substance of the earth which lies near enough to the surface to be examined by man, oxygen forms the principal constituent.

Of this, however, it is only that which is in the air that is free. All that is in the water, and in the earth, has its prodigious chemical affinity, or its "voracious appetite," as Lawrence called it, *satisfied* with the substances with which it is already combined; and there are very few substances for which it will quit those which it already thus holds to enter into any new combinations. That which is in the air, however, is free, or at least comparatively free, and is ready to attack and devour any thing that comes within its reach.

When I say all that is in the water, I mean all that is in the combination which forms the *substance of the water itself.* There is usually a quantity of common air mingled with water, and this air contains its proper proportion of oxygen, which is free to act upon other substances, when they are wet with the water, just like the oxygen in any other air.

Oxygen that is free has two ways of devouring substances that come within its reach. One is quiet and slow, and the other excessively rapid and violent. At the ordinary temperature of the atmosphere, that is, when the substances which it is to act upon are moderately cool, it consumes them slowly and quietly. It eats into iron in this way, forming rust; for iron rust is a combination of oxygen and iron, or, as the chemists call it, an *oxide of iron.* It gradually consumes the leaves and dead wood that fall in the forest, producing what is called vegetable decay. It devours in the same way, or helps to devour, every dead animal body, and carries off in gases, into the air, or into solutions into the ground, the substances which compose it. In these, which are its *quiet* ways of acting, it is incessantly occupied all over the earth—consuming slowly and silently all the animal and vegetable substances which are produced on the globe, attacking each one as soon as death puts the substances of which they are composed into its power. Some of the new combinations which it thus makes float away into the air, and some are carried by rains into the ground.

And what is very curious, and also fundamentally important to one who wishes to understand the grand operations of nature, the processes of vegetation consist in the main of the *recovery of these substances from their combinations with oxygen, through the agency of the heat and chemical power of the sun,* and in reconstituting them in the forms of vegetable and animal life. They continue in these forms, protected in some mysterious way by the vital principle, until death comes to set them free again, and to put them within the reach and at the disposal of oxygen once more.

The two principal substances which the sun employs in the construction of the tissues of plants, and which it has to recover, by its chemical force, from the possession of oxygen, are *carbon* and *hydrogen*. These are the chief constituents of vegetable and animal substances. The oxygen holds the hydrogen in water, and the carbon in a portion of the air called *carbonic acid* gas. But in some mysterious way, not at all well understood, the sun, by the exercise of a prodigious chemical force, working in the leaves of plants, separates these elements from their combinations, and sends the oxygen off, empty and hungry, back into the air, while the carbon and hydrogen are conveyed away through the vessels of the plant, and formed into wood, bark, leaves, flowers, and fruit. The oxygen can not touch them again so long as life remains. When these substances are transferred to the bodies of animals —as the leaves of grass, for instance, eaten by oxen or sheep—or fruits or grain by man, the *animal life* protects them. But when they are no longer thus protected, whether by being rejected from the system or by the death of the animal, then the turn of oxygen comes again, and they are carried off by it into the two grand storehouses of nature, the soil which covers the surface of the ground, and the air.

Of course a statement made in this simple form gives only a very general idea of the leading aspect of the phenomena. The variations and exceptions from this general statement, and the endless multiplicity of detail which result from the action and interaction of all the forces involved, make the whole operation so intricate that the human mind can never hope to unravel all its complications. It will be of advantage, however, to the young student to keep in mind the general idea here expressed as tending to give system to his thoughts, and enabling him the better to understand and appreciate the individual facts which may from time to time come under his knowledge.

The principles stated summarily are these:

1st. That oxygen is the most abundant substance in all that portion of the natural world accessible to us, and the great agent by means of which all the principal operations of nature on the surface of the earth are performed.

2d. That the active portion of this oxygen is mainly that which exists in a feeble union with nitrogen in the air; that which exists in the earth and in the water being confined in fixed combinations, and thus reduced to a condition of inertness and repose.

3d. That the great processes of animal and vegetable life consist generally, and in the main, though with an infinite number of variations and exceptions in detail, in separating certain substances, the chief of which are hydrogen and carbon, from their combinations with oxygen, by the superior force of the chemical action of the sun acting in the leaves of plants, and in combining them in new forms, namely, those of vegetable and animal tissues. That they are protected in these new combinations in some mysterious way by the principle of *life;* but that when this fails, oxygen again resumes its power over them, and bears them away into the earth or into the air, and holds them till they are once more taken in by the roots or leaves of plants, and impressed again in the service of *life.* And so the work goes on in an eternal round.

The material substances which form the human body are subject to the same law. When the body, after death, is

TROPICAL FOREST.

allowed to take the course which nature intended, the elements which compose it being no longer of use in the service of life in one form, are immediately prepared to enter it in another. They soon become beautifully transformed, and appear again in the flowers of the garden, the foliage of the forest, the verdure of the meadows and fields, or in some other form of the universal bloom with which vegetation embellishes the world. Man, it seems, however, often does all he can to prevent this transformation. By his tombs, his sarcophagi, his caskets, and his chemical embalmings, he strives to hold back the substance of the lifeless body from this natural and charming destination, and, by stopping it in its transition, to retain it forever in a condition of ghastly and revolting decay. In doing this he is striving to thwart the intentions of nature, which it would seem, in such a case, he ought to regard as the will of God.

But to return. In accordance with what has been explained, if we were to go into a forest some day in midsummer, and had eyes delicate enough to see what was going on there, we should perceive in all the leaves of the trees the incessant movement of a vast force, brought by the rays of the sun, and employed in separating the hydrogen and carbon from their combinations with oxygen in carbonic acid gas and in water, and sending the oxygen off free; and, on the other hand, on the ground, and in the lungs and spiracles of every insect, beast, and bird, an equally active movement, in which the oxygen is engaged in recovering possession of the material of which it had before been despoiled, and re-forming carbonic acid and water again, to furnish the future processes of life with fresh supplies. In a tropical forest these processes go on with redoubled energy, on account of the extraordinary force of the solar radiations, which are always vertical, or nearly vertical there.

It thus appears that, since the element of oxygen is every where and always at work over the whole surface of the globe, and that it is the fate of every living thing to be sooner or later devoured by it, and that even all that the lions, and tigers, and vultures, and rats devour in the first instance they have to give up, as well as to surrender the substances composing their own bodies, in the end, to the voracious rapacity of this omnipresent element, Lawrence was perfectly justified in designating it as the Great Devourer.

We must not, however, fall into the mistake of supposing that by the great devourer is meant fire. It is not fire, but oxygen. Fire is only an effect which oxygen produces in *one* of its many modes of seizing its prey; and the substances in which fire is produced by its mode of consuming them form an infinitely small part of the whole amount which it devours. By far the largest portion, indeed almost the whole, is consumed by a kind of action which, though universal, all-pervading, and irresistible, is silent, gentle, and for the most part entirely unobserved.

But it is time to bring this lecture to an end, and to proceed with the account of the embarkation of the party of travelers on board the Scotia.

CHAPTER III.

GOING ON BOARD.

JOHN had been so much interested in what Lawrence had explained to him about the great function of oxygen in relation to the vast processes of vegetable and animal life, and in rendering possible their perpetual renovation, that he forgot the question about the comparative combustibility of wood and iron.

And here, perhaps, I ought to remark, that although, in view of the rapacious appetite, so to speak, of the element oxygen, and the enormous quantities of the other elements which it continually consumes, it is natural enough, still, perhaps, it is hardly fair, to stigmatize it as simply a devourer. Its great function being, as we have seen, to receive the materials which have been employed by the principle of life, and, after having fulfilled their purpose, have been abandoned, and to convey them away, and keep them in its custody in the two great storehouses of nature, *the soil* and *the air*, until they are again required, it might, perhaps, as justly be designated as the great *receiver and custodian* of nature's stores, ready to deliver them at any time on demand by the sun, as to be called a devourer; and to consider it as serving and co-operating with the sun in sustaining and carrying forward the vast cycle of birth, life, death, and dissolution in its eternal round, rather than as acting the part of an antagonist and enemy. The facts, however, are all clear, and in their general aspect easily to be understood; and they have a very grand significance to those qualified properly to appreciate them, under whatever figurative disguises our fancy may amuse itself in representing them.

About an hour after breakfast, while Lawrence and John were sitting in one of the small parlors, each with a light coat over his arm, and a small valise in his hand, an attendant of the hotel came in and told them that their carriage was ready.

So they went down the broad staircase, and through the wide open hall—which was crowded with people coming and going, and encumbered with vast piles of trunks and other baggage—until they came to the great entrance door, where a scene of extraordinary noise and confusion opened before them. The street was full of omnibuses, cars, carriages, and trucks, that were making their way as well as they could around and among each other, with thundering din. A long row of coaches and cabs were drawn up along the edge of the sidewalk in front of the hotel, and great crowds of foot-passengers were going and coming on the broad flag-stone walks—clerks and men of business hurrying along, eager to reach their counting-rooms before bank-hours—elegantly dressed ladies, walking in pairs—groups of school-boys and school-girls, with little packages of books fastened together by a leather strap in their hands, and nurses taking children out to walk, or propelling babies in pretty perambulators. John, not having been much in the city, was much impressed with this scene.

Directly before the door was a carriage, and John, on looking up to the driver's seat, saw that Flippy was sitting there by the side of the driver.

The waiter who had notified Lawrence and John that their carriage was ready, advanced and opened the door of this carriage as if for them to get in.

"This is not our carriage," said John. "This is Flippy's."

"I thought he belonged to your party," said the waiter.

Just at this moment Lawrence and John heard a lady's voice saying,

"That is not our carriage. Flippy, come down!"

"Yes, mother," said Flippy. "He says he's going to the Scotia."

"Who says so?" asked his mother.

"The driver," replied Flippy.

"That's nothing," said the lady. "He is going with another party. Come down! Here's our carriage out here. Make him come down, Edmund."

These last words were addressed to a gentleman who had just at that moment appeared at the "Lady's Entrance" to the hotel, where the lady was standing. He had his hands full of bags and parcels, and seemed worried and bewildered. He looked first at the carriages, and then up at Flippy, and then at his wife, and did not appear to know what to do.

At length he seemed to comprehend the situation, and called out imperiously,

"Flippy, come down from there this instant! That is not our carriage! Here's our carriage!"

But imperiousness in the manner of giving commands is a very inefficient substitute for established authority in enforcing them. The most stern and determined tone of voice in issuing an order will fall powerless unless the recipient of it has been trained to obey. Flippy did not move.

"Flippy," repeated his mother, "come down this instant!"

"No," said Flippy. "There is no place for me to ride outside in your carriage, and I'm going in this. It don't make no difference. It's going to the same place."

"But the gentleman will not be willing to have you go in his carriage," said his mother. "He has engaged that carriage for himself. Come down!"

Here Lawrence turned to the lady and said that, if she had no objection, her son could go in his carriage perfectly well. It would be no inconvenience to him.

The lady looked first at Lawrence, then at Flippy, then at her husband, and seemed very much perplexed, as she exclaimed, "What a vexation!" In the mean time the hubbub all around her increased. The hotel waiter had put two enormous trunks upon the carriage which had been engaged for her, and was helping her husband to put in the bags and parcels. Different drivers were calling upon each other to "hurry up," and to "move on." Finally, without stopping really to decide the question, she found herself so hemmed in by the necessities of the case, that she allowed herself to be helped into the carriage. Her husband stepped in after her, the door was shut, and the waiter called out to the driver, "*Jersey City!*" "*Steamer Scotia!*" and the carriage moved on.

"I wish, Mr. Gray," said the lady, as the carriage moved away from the door, "that you would teach Flippy to obey a little better. You have no authority over him at all."

"My dear," said Mr. Gray, with a gesture of impatience, "what can I do? I ordered him positively to come down. What more could I do?"

"We don't know any thing about those people that he has gone with," continued Mrs. Gray, without taking any notice of her husband's reply. "It is very annoying!"

"I dare say they are very respectable people," said Mr. Gray. "I did not see any thing out of the way. But that's no excuse for Flippy."

In the mean time the carriage of Lawrence and John had begun to move too.

"Good!" exclaimed John, in a tone of great satisfaction. "We're off! But, Lawrence, you should not have encouraged this boy in disobeying his mother by telling him that you would let him go with us."

"I did not tell him that *I* would let him go with us," replied Lawrence. "I told his mother that *she* might let him go with us, if she chose."

"That comes to the same thing," said John.

"Yes," replied Lawrence, "it comes to the same thing in the end; but there may easily be two ways leading to the same end, and yet one of them be right and the other wrong."

"*I* think you encouraged him in his disobedience," said John.

"Do you?" said Lawrence. "Then you must fine me for a misdemeanor."

"Fine you," repeated John.

"Yes," replied Lawrence. "I will make a bargain with you, if you will agree to it, that every time either of us commits a misdemeanor he is to be fined five cents; and every time he is guilty of a less offense than a misdemeanor, such as we might call a *peccadillo*, he shall be fined two cents. You shall be treasurer and shall keep the money, and when we get to Paris we will spend it in a ride out into the environs of Paris."

John readily agreed to this, but, after having agreed to it, he asked what the difference was between a misdemeanor and a peccadillo. Lawrence replied that there was not, in fact, any well-defined difference, except that a peccadillo was a very light offense, and a misdemeanor was something more serious.

"We can understand, if you please," said Lawrence, "that misdemeanor means something that is morally wrong—that is to say, something wrong in respect *to the feelings* *and intent of the heart*—such as disobedience in ourselves, or the encouraging of disobedience in others; while a peccadillo is something that affects mere outward action."

"Such as what?" asked John.

"Such as drumming with your knife on your plate from thoughtlessness," said Lawrence, "while waiting for your dinner to come."

John laughed and said he should not do that. But Lawrence said he might do things like that, that is, things that showed no evil intention, but were only acts of thoughtlessness, which were disagreeable to other people. John said if he did he was willing to pay two cents for each one, on condition that Lawrence would do the same.

So it was agreed that for every misdemeanor the guilty one was to pay five cents, and for every peccadillo two cents, into a common treasury, and that the money so collected should be spent in an excursion when they reached Paris.

Lawrence exercised a little innocent artifice in making this arrangement with John. He adopted it as an easy and good-natured method of maintaining that slight degree of supervision and control which is usually necessary, or, at least, often desirable, in such cases, on the part of the older over the younger of two young people making a journey together. He had no expectation of actually fining John for any shortcomings that he might observe, for John was a considerate and careful boy, and he was convinced that it would be very seldom that he would do any thing requiring interposition on his part. And then, moreover, he supposed that when accused, he would defend himself, and that in the end the fine would not be imposed. On the other hand, he had no doubt that John would watch him very closely, and often charge him with misdemeanors or peccadilloes; and that in such cases, after a little feeble defense of himself, he should always yield, so that it would be he himself who would have all the fines to pay. He thought, however, that the incidental conversations which would arise in discussing and settling the questions would be the means of making John very careful about his demeanor, and enable him, that is, Lawrence, to check him when he was wrong, and thus to exercise a proper authority over him in a manner which, though in a sense playful, would still be effectual, without tending at all to irritate or vex the boy, as open fault-finding would have done.

In the mean time the carriage went on, threading its way among the carts and omnibuses, through various streets, drawing gradually nearer to the river, as John perceived by glimpses of the water which now and then came into view. At length it stopped. It had been stopped several times before by "jams" of vehicles, but there seemed to be no jam here.

"It is the ferry," said Lawrence.

"Is there a ferry to cross?" asked John.

"Yes," replied Lawrence, "we go across the North River. The Cunard wharf is in Jersey City. We call it sailing from New York, but it is really from New Jersey."

Presently a heavy jingling sound was heard, occasioned by the running of the great iron chain by which the ferry-boat was drawn up and secured to the landing-bridge, and immediately a great gate was opened, and a long train of ponderous vehicles began to come out, and, as soon as they had passed, the train that had been waiting began to go in. The boat was large enough to contain two long lines of these carts and carriages, with saloons for passengers on each side. Lawrence and John remained in the carriage, but John looked out at the window and called to Flippy.

"Flippy," said he; "hallo!"

"Come up here," said Flippy in reply. "Come up here, and see how this ferry-boat is jammed full of wagons and teams."

"I can't get up there," said John.

"Yes," said Flippy, "you can climb up out of the window."

"Would you?" said John, looking back at Lawrence.

"*I* should gain by it, at any rate," said Lawrence.

"How so?" asked John.

"I could fine you for a peccadillo."

"Would that be a peccadillo?" asked John.

"Yes," said Lawrence; "climbing out of the window of a carriage to get to the driver's seat with another boy, in crossing the Jersey City Ferry, to embark for Europe, would be a first-class peccadillo. I don't think two cents would be fine enough for it. But I suppose I should have to be contented with two cents, since that was the law we made. Of course we must go according to law."

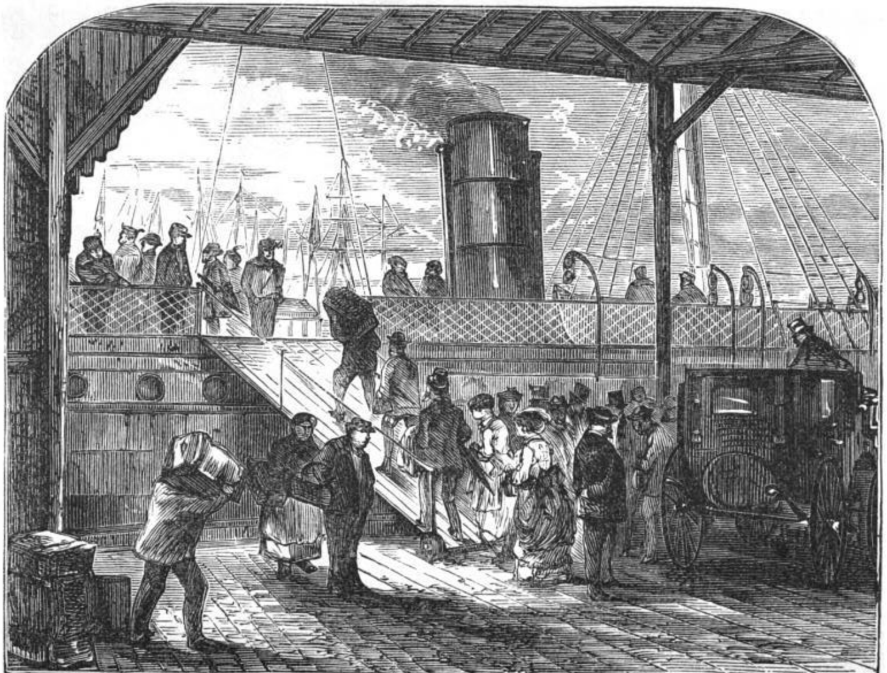
"But you might call it a misdemeanor," said John, "and so make the fine five cents."

"No," replied Lawrence, "it would not be a misdemeanor on our system, because there would be no *moral* considerations involved. Unless, indeed, I forbade your going, and you should disobey; then it would be a misdemeanor."

"John," said Flippy, calling out from his seat in front, "are you coming?"

"No," said John.

Soon after this a little bell was heard, and the motion of the boat was immediately felt to be checked. A moment following there was a little bump, and then a jingling sound, caused by the running out of the great chain by which the boat was to be drawn up snug to the landing-bridge. The long trains of carriages and wagons then moved on out of the boat, and the one which con-



THE EMBARKATION.

tained our travelers took the direction toward the Cunard dock.

Arriving at the dock, the carriage entered, through a great gate, into a spacious inclosure, with piers, and steamers, and masts, and vast iron chimneys painted red, and carts, and carriages, and piles of boxes, and heaps of trunks and other baggage, and groups of sailors pulling in concert upon ropes, and other such nautical sights and sounds, combining to form a very busy and noisy scene. The carriage went on under a long shed, passing by several other steamers, until it reached the Scotia, and then stopped. Lawrence and John got out, Flippy at the same time climbing down from his high seat over the forward wheel. They took their bags and parcels in their hands.

"Let me have one," said Flippy.

One of the hands from the steamer came and took from them the heaviest of their packages, and then they all went up the gangway plank on board. The gangway plank, as they called it, was a broad and well-constructed bridge, with a good substantial railing on each side, so that there was no danger of falling into the water in going on board.

John, who had never been on board of any but river and Sound steamers before, was quite impressed with the solid and massive character of every thing that he saw around him as he entered the ship. The bulwarks which bordered the main deck were seven or eight feet high, and seemed to him to be a foot thick, and very solid. The main saloon, with its long row of windows—the flights of steps seen here and there—the paddle-boxes—the monstrous frames supporting the various timbers on the deck, some apparently connected with the machinery, and others serving purposes which he could not understand—the long and slender, but very solid-looking bridge, running across from the top of one of the paddle-boxes to the other, which served for a walk and look-out for the captain and pilot—and, more than all the rest, a view of the immense engines, which were to be seen in looking down through very large square openings in the decks, guarded by massive railings so high that Flippy had to stand on tiptoe to look over—these and many other such things combined to impress both Lawrence and John very strongly with the dignity and grandeur of an ocean steamer.

They only took a glance at these things in passing, and then went down below to find their state-room and deposit their bags and parcels. Flippy remained on the upper deck to watch for the carriage of his father and mother. Lawrence and John went through a passage-way which opened on the main deck between the dining saloon and what seemed to be an immense china closet, then descended a winding staircase with steps covered with plates of metal, then passed through a long passage-way with doors opening into the various state-rooms on each side. They began to look about for the numbers denoting their room, when a pleasant-looking woman met them and directed them. They found their room at the end of a short and narrow passage which led between two inner state-rooms. Theirs was an outer one—that is, next the side of the ship. When they entered it, John found that, though called a state-room, it was really rather a closet than a room. On one side, which was, of course, the side next the sea, there was a small round window quite high up. It was fitted with one very thick pane of glass, which was set in a very solid and heavy brass frame. This frame had a hinge on one side, and very strong screws on the other side, which, by means of a stout handle, could be screwed tight into a socket on the side opposite to the hinge, so as to fasten the window securely in heavy weather. The window was open when John went into the room, and the first thing he did was to climb up upon a very narrow cushioned seat under it, and look out. But there was very little to be seen.

On the other side of the cabin were two berths—that is, narrow beds made on shelves against the wall, one above the other; and at the end opposite the door was a fixed wash-stand, with pitcher and basin set in a marble top, and a cupboard below. Above it was a shelf with a decanter and two tumblers upon it, set in holes to prevent their sliding off the shelf in a heavy sea; and there were two looking-glasses, and two or three massive hooks to hang clothes up on, and two great round life-preservers, and various other conveniences.

John looked at all these things one after the other, and then said,

"It is little enough—the place; but I don't see but that they have put every thing in it that we want."

"Yes," replied Lawrence; "and things that I hope we shall not want—the life-preservers."

These life-preservers were great round rings, and John found, by rapping upon one of them, that they were hollow. They were of such a size that a man could put them over his head and shoulders, and then draw his arms up through them, and so float in the water, supported by the buoyancy of the life-preserver under his arms.

"Yes," said John, "I hope we shall not have to use them on this voyage, but I should like very much to have one of them to play with when I go in swimming in the river at home."

Lawrence and John stowed their parcels and bags under the lower berth and under the seat, and then Lawrence asked John which berth he would have for his, the upper or the under one.

"The upper one," said John.

"You'll have a hard climb to get up to it," said Lawrence.

"That's the reason I like it," said John. "I like to climb; and, besides, it is easy enough to climb up into that berth."

So saying, John stepped upon the seat beyond where his

THE STATE-ROOM.

cousin was sitting, and thence upon the wash-stand, and from the wash-stand he clambered into the upper berth, and, crouching down in it on his hands and knees, he began to look out through the little round window, while Lawrence, making a desk of his little valise, which he held in his lap, began to write a farewell note to somebody or other.

"See!" said John; "I can look out at the window all the way."

"There won't be much to see," said Lawrence, "when we are out in mid-ocean."

"I may see a ship," said John.

"We meet very few ships on the open sea," said Lawrence.

"I may see an iceberg," said John.

"I hope we shall not meet any icebergs at all," replied Lawrence.

"I may see a whale," said John.

"True," replied Lawrence, "you may possibly see a whale."

"At any rate," said John, "I like the upper berth the best."

So it was all arranged, and Lawrence and John soon afterward left their cabin and went up on deck to see what had become of Flippy.

CHAPTER IV.

LEAVING PORT.

On the evening of the first day of the voyage, when the steamer, having taken all her passengers on board, had sailed down the harbor, and had dismissed the pilot, and was now proceeding, in reality, very swiftly, though apparently very slowly, out to sea, John and Flippy were sitting together on the deck watching the land, that was now so distant as to look like a long, low line of cloud near the horizon. The sea was smooth and the air was calm. But the rapid motion of the ship produced something like a breeze over the deck, which was, moreover, so cool as to make it quite agreeable to find some shelter from it. There were, however, plenty of sheltered places furnished by the immense paddle-boxes and smoke-pipes, and by the fixtures around the hatchway, and around various other openings through the decks. All these places were filled with groups of ladies, sitting upon camp-stools and folding-chairs, enjoying the evening air and the smooth sea, and congratulating each other on their being favored with so charming a commencement of their voyage. Some of the ladies were talking with each other cheerily, and seemed quite light-hearted and gay. Others were silent, thoughtful, and sad. This was very natural, for among them there were, on the one hand, many whose hearts were entirely at ease, as, for example, brides setting out, full of gladness and hope, on their wedding-tour, and young ladies on their way to Paris, with bright anticipations of the joys and gayeties that awaited them there, and European mothers returning gladly to their homes and families in the Old World, after having accompanied their husbands on a business tour to the New; while, on the other hand, there was *here* an American mother leaving young children at home to accompany a husband in failing health on a foreign tour, equally anxious about the sick one taken with her and the helpless ones left behind, and *there* a youthful couple in mourning for an only child, who, after vainly contending with their grief for half a year in their own desolate home, were now going to attempt to aid themselves in diverting their minds a little from their overwhelming sorrow by the scenes and excitements of a foreign tour, and were already half sorry that they came.

As for the brides, however, perhaps I have placed them in the wrong class, in the above enumeration, in representing them as leaving their native land with hearts filled with gladness and joy. The gladness and joy, in the case of such a bride, are mingled with sadness and fear. She can not help feeling that she has sundered forever the tie which has bound her to all that have ever been most dear to her, and committed herself irrevocably to a new bond, her faith in which, though she feels sure that it is implicit, complete, and unwavering, is, after all, not wholly unmixed with those half-misgivings which we always feel in intrusting ourselves to what is new and utterly untried.

Besides these various groups, who were seated in different nooks and corners, upon camp-stools, folding chairs, and cushioned settees, there were groups of children running to and fro, delighted with the new acquaintances which they were making among each other, and with the novelty and strangeness of the scenes into which they had been so suddenly brought; for the transition from the tumult and noise of the hotels and crowded streets of New York to the quiet scenes, and to the steady and gentle motion of the ship, gliding over smooth water, far out at sea, now that it was over, seemed to them like a dream.

John and Flippy were standing together, just before eight o'clock, looking down through an opening in the deck, and through the machinery below, to a place far, far down in the hold, where they could see the forms of half-naked men shoveling coal into the mouths of furnaces glowing with furious heat, when Lawrence came to them and asked them to go down with him into the saloon.

"They are going to perform a very curious chemical experiment there," said he, "and I want you to see it. At least I would like to have *you* go, John," said he. "Flippy can do as he likes. I am sure you will be interested in it. As to Flippy, I don't know."

"What experiment is it?" asked John.

"It is the fusion and combustion of a hydrocarbon," said Lawrence, gravely.

"What does it do?" asked Flippy.

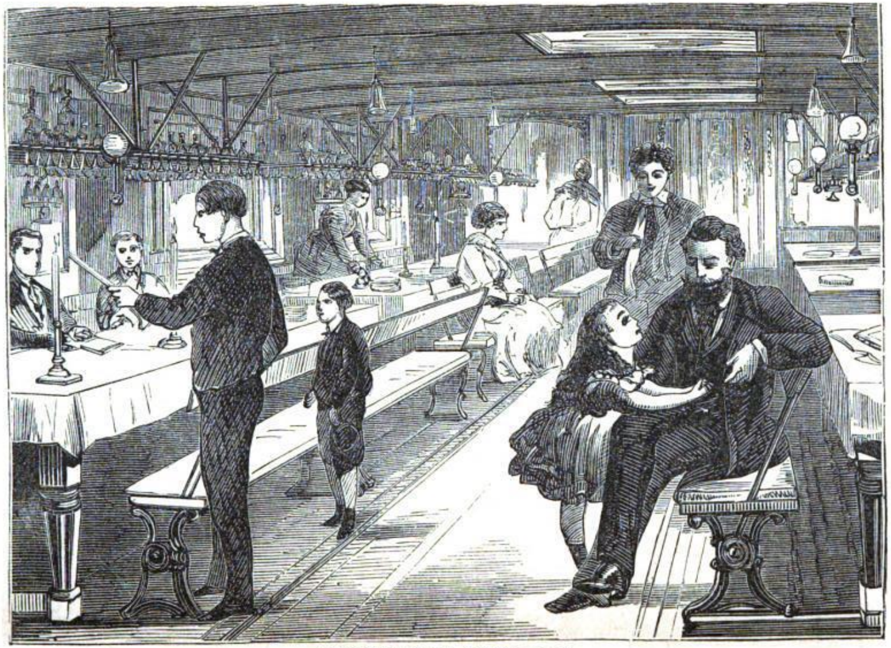
"It does not do any thing except make a bright light," said Lawrence.

"I should like to see it, if it does that," said Flippy, "and I'll go."

So they all went down into the saloon together.

The saloon was a long room elegantly decorated, and brilliant with mirrors and plate-glass. It was furnished with a long row of tables on each side, a broad passage-way being left open between them in the middle. There was a range of handsomely and comfortably cushioned benches on each side of the tables—one, of course, back against the walls, and the other on the side of the passage-way. Lawrence and John had been in this room some times before during the day. Indeed, they had taken dinner here, and now the tables were set for tea.

Lawrence led the way between two of the tables, and



COMBUSTION OF A HYDROCARBON.

took a seat upon a cushioned bench, or sofa, as it might, perhaps, be called, that extended along the wall. The two boys followed him and took seats by the side of him. The tables were all set for tea, and conspicuous among the other things that were placed upon them were two long rows of tall candles in silvered candlesticks, which extended along the whole length of the room.

"Who is going to perform the experiment?" asked John.

"One of the waiters," replied Lawrence.

John was rather surprised at this, and, looking up at Lawrence, he thought he observed something like a suppressed smile lurking in the expression of his countenance.

"Now, Lawrence," he exclaimed, "you have been making fools of us! I'm sure you have; and if you have—"

"No," replied Lawrence, "you'll find that it will turn out just as I said. I said they were going to perform a very curious chemical experiment, and there the waiter comes to do it now."

As he said this he pointed toward the door, where a steward—they always call the waiters at sea stewards and stewardesses—was coming in with a lighted candle in his hand, with which to light the other candles.

"He is going to light the candles," said Lawrence, "and the burning of a candle is truly a very curious chemical process."

"You said it was something extraordinary," rejoined John, "and there is nothing extraordinary at all in lighting a candle. You made fools of us, and I think it was a peccadillo or a misdemeanor. I think it was a full misdemeanor, and that you ought to be fined five cents. Oughtn't he, Flippy? He brought us down here to show us something extraordinary, and it is nothing but lighting the candles, which is one of the most common things in the world."

"*Curious*," rejoined Lawrence. "I think I said curious, and I'll leave it to Flippy if it is not so. I will explain to him and to you all about the burning of a candle, and if he does not decide that it is curious, I will admit that I made fools of you, and that it was a peccadillo, and so I will pay the fine."

"A misdemeanor," said John; "it was a full misdemeanor."

"Very well," rejoined Lawrence, "a misdemeanor. I will agree to pay the fine for a misdemeanor—five cents, if Flippy so decides. But they are coming in to tea now, so we will wait till after tea."

CHAPTER V.

COMBUSTION.

THE people came in very irregularly for tea, and the boys proposed that they should go up on deck a little while to see what was going on, and so return afterward and hear what Lawrence had to say about the burning of candles. Lawrence said that was just what he should like, and so the boys went away. He remained in his seat and began to read.

The reason why he was glad to have the boys go up on deck for a while was that he wished to have their curiosity satisfied in respect to the visible scenes and images which presented themselves to view on board the ship, before he attempted to lead their thoughts to the more hidden mysteries of chemical action. In other words, he did not wish that, while he was explaining to them what was curious in the burning of a candle, their minds should be interested in something else. A great deal of excellent advice and instruction offered by older persons to younger is lost, in respect to its effect, simply by being ill-timed—that is, by being offered at times when the minds of the listeners are preoccupied with other thoughts or other desires.

It was half past eight o'clock when the boys came down.

"Did we stay too long?" asked John.

"Not at all too long," said Lawrence. "The longer you can find something to amuse you on deck the better."

"It's getting cold up there now," said John, "and so we have come down to hear about the candle."

So the boys sat down, one on each side of Lawrence, upon the seat along the wall, back of the table, and Lawrence began as follows:

"You remember what I told you, John, about the sun's working all day in separating carbon and hydrogen from the oxygen in water and air, and delivering these elements to the control of the principle of life in the plant; and that they remained under the control of this principle while they continued parts of a living being, whether plant or animal, and that at length, when they were thrown off, or when the plant or animal dies, the oxygen that is free in the atmosphere, and in the air contained in water, attacks them, and recombines with them slowly, and holds them strongly until the sun takes them away from it again in the leaves of new plants?"

John said that he remembered about this, but that Flippy was not there when he explained it, and that perhaps he had better explain it to Flippy again.

"No," said Flippy, "I don't care about it much. All I want to hear about is the candle, so as to see if Mr. Lawrence is to pay the fine."

"Then," said Lawrence, "I will begin at once about the candle; though first I must say that the chief elements that the sun takes away from the oxygen in the leaves are hydrogen and carbon, and these are the two substances that are chiefly used in making all vegetable and animal substances.

"You can understand and remember that, Flippy, at any rate," added Lawrence, turning to Flippy, "namely, that all vegetable and animal substances that will burn when they are dry are composed chiefly of *hydrogen* and *carbon*, and so they are called hydrocarbons. Hydrogen burns alone with a faint bluish flame, that gives very little light. Carbon burns without any flame, but becomes of a very bright red heat. When they burn together, the hydrogen forms the gaseous portion of the flame, while the incandescent particles of the carbon that are in it—that is, the particles of carbon that have become red hot or white hot, give it its body and brightness."

The boys looked at the flame of the candle to see whether they could detect the incandescent particles of the carbon in it.

"There are a great many different hydrocarbons," said Lawrence. "Wood is substantially a hydrocarbon, though the term is more generally applied to such substances as resin, wax, tallow, and oils, which consist almost exclusively of hydrogen and carbon, while wood and other such vegetable and animal tissues contain a considerable portion of other substances. Anthracite coal is a *carbon* simply, for it does not contain any hydrogen, and so will not burn with flame; and bones, and shells, and other such substances are not hydrocarbons at all, as is shown by the fact that they can not be set on fire in any way."

Lawrence then proceeded to name a great variety of substances, and to ask the boys whether they were hydrocarbons or not. Even Flippy soon began to be quite interested in answering these questions; for, just as it is always a pleasure to a boy to exercise his limbs and external organs in new ways that are pointed out to him, provided the things proposed to be done are such as he can do, so he is always interested in the mental action of comprehending any ideal distinction which is explained to him—that is, a distinction which he does not see in the objects themselves actually before him, but which he has to conceive of in his mind.

I knew a boy once—a little fellow who had not yet learned to read—whose brother gave him an excellent lesson one day in explaining to him the meaning of the word quadruped, and then naming to him a great number of animals, and asking of each one whether it was a quadruped or not. He called it a lesson; and a very useful lesson it was for the child, as it exercised, and so helped to develop, his thinking powers. And so interested was the child in the lesson that he asked for another. So his brother the next day explained to him the meaning of the word *biped*, and then named to him again all the various animals that he had named the day before, and asked him if they were bipeds. Of course the answers would be all the reverse of those which he had given before, when asked if they were quadrupeds.

If you try this experiment, or any other which calls into action, not too severely, the thinking powers of young children, you will find that they will be greatly interested in such an exercise of their mental faculties. Only you must be careful not to make the work too difficult for them, and you must be careful to choose your time, as Lawrence did, when their minds are not preoccupied with other things.

It was on this principle that Flippy became interested in being able to distinguish the class of hydrocarbons from all other substances. Lawrence talked about them for some time in a cursory manner—that is, without attempting to impart any special information, in order to let the boys become perfectly familiar with the word, and with the general character of the class of substances to which it was applied.

Carbon and hydrogen are both combustible, but they burn in very different ways, and produce very different results. Lawrence, in order to interest Flippy in such subjects, and thus to open to his mind new sources of instruction, directed a considerable portion of the conversation particularly to him, for John was greatly interested in such subjects already. This was simply because he knew many things about them already, while Flippy had no knowledge of them at all. For, as I have said before, people are generally more interested in learning *more* about that of which they already know something, than in beginning to learn about something of which, as yet, they know nothing at all.

There is, indeed, something very curious about the burning of carbon and hydrogen, but, in order that the reader may understand it clearly, it is necessary that I should first explain what burning actually is. Oxygen has two ways of seizing and combining with those substances for which it has a strong affinity. One is the slow and gentle way which it takes with these substances at ordinary temperatures, as, for example, when it combines with iron to form rust, or when it combines with animal and vegetable substances, which are no longer protected by a principle of life, in the processes of animal and vegetable decay. These combinations take place at ordinary temperatures. If the substances are too cold, as when, for instance, in the case of animal and vegetable substances, they are frozen, then it can not take place at all.

This is the philosophy of preserving articles of food, for example, by freezing them, or packing them in ice—that is, by this treatment they and the oxygen around them are kept so cool that they can not combine—in other words, what we call decay can not go on.

If now, however, we increase the temperature of the substances gently, as, for example, taking them out of the ice, and exposing them to the warmth of a common summer day, then they begin slowly to combine. The wood, if it is wood, begins to decay, which decay consists essentially in its being combined with oxygen, and the new combination being carried off into the air. This is so slow a process, however, that a heap of logs lying on the ground would be several years, ordinarily, in being decomposed and conveyed away.

If now, on the other hand, the temperature of the wood is raised to a great heat—about the heat, for example, of that of red-hot iron—then, for some mysterious reason or other which nobody understands, the oxygen begins to seize upon the carbon or hydrogen, or both, of which the wood is composed, *with the utmost avidity and violence.* It then becomes truly a devourer. And the violence of the action shows itself in the development of an excessive degree of additional heat. This is what we call burning. The slow and gradual consumption of a substance by oxygen, without the development of great heat, we do not call *burning;* we call it *decay.* Sometimes it is called slow burning, or slow combustion, because the nature of the two processes seem to be essentially the same, except in the rapidity with which they take place. But the term *burning*, or, rather, *combustion*, is strictly applied only to those processes of the combination of oxygen with carbon or hydrogen which are so rapid and violent as to be attended with the development of an intense degree of heat.

I say burning *or* combustion, as if these two terms meant the same thing. But they are not, by any means, precisely synonymous. Burning is the term used in common parlance, while combustion is the scientific term; and, as is usually the case in respect to common and scientific terms, the former is more loose and general in its signification, being applied to many things which *seem* alike in external appearance and in their effect upon the senses, though they are, or may be, quite different in their essential natures; while the scientific term is used much more precisely, and is applied only to a certain class of effects which are of precisely the same nature.

Thus the word *burning* is applied to a great number and variety of effects produced by great heat, such as the burning of lime, in which the action of oxygen, so far as the lime is concerned, has nothing to do; the burning of a boy's finger in a candle, which does not necessarily imply any chemical change at all, but only a sensation produced in the nervous system. But the term combustion is only applied to the process through which oxygen, or some similar substance, produces intense heat and certain destructive effects, *through the extreme violence and intensity of its action.*

It is important, however, for the reader to understand that by *destructive effect* we only refer to the particular combination in which the substances existed, and not to the substances themselves. No elements can be destroyed, or even injured, or changed in any degree, either in quantity or quality. They can only be separated from their present combinations, and set free to form new ones. Thus, when a boy throws a letter which he had written into the fire, and it is burnt up, nothing is really destroyed but the letter as a letter. The carbon and hydrogen, and the other substances in small quantities that composed the paper, and the iron, and oxygen, and other substances in small quantities that composed the ink, would not be changed at all. It would only be the letter *as a letter*—that is, the particular combination of these substances that would be destroyed. The carbon and hydrogen would go up the chimney in the draft, and some of the other substances would remain, to fall finally into the ashes; but these elements, though they might be mixed with various other substances as they lay upon the hearth, or floated away into the air, would in themselves be, in their own essential nature, entirely unchanged—the same precisely that they were before they went into combination in the leaves of the cotton-tree, out of which the tree formed the cotton, of which the spinner and weaver formed the cloth, of which the paper-maker made the paper on which the boy wrote the letter that was burned.

The term combustion is thus applied to the process by which oxygen seizes upon certain other elements previously existing in other combinations, and forms new combinations, doing this with such violence and intensity of action as to develop light and heat. These substances which are capable of being thus seized and devoured, as it were, by oxygen, are called combustibles. And this reminds me of the question which had been raised between Lawrence and John, whether wood or iron was most strictly and completely combustible, which question they had not yet settled, and which they seemed to have forgotten. But they had not forgotten it. It will come up again by-and-by.

CHAPTER VI.

FLIPPY A REFEREE.

Lawrence explained all these things in relation to the nature of combustion to Flippy and John. John listened to it all with great attention, and even Flippy seemed more interested in it than one might have expected. He said at last that he thought he should understand it better if he could only see some of the carbon and hydrogen, so as to know exactly how they looked.

Lawrence replied that there was something very curious in respect to the question of seeing those substances, which was that they, like all other elementary substances, changed their form and appearance, and all other sensible qualities, in fact, in their different states and combinations, so as to assume every possible disguise.

"It is somewhat," he said, "like the case of the substance of the slate-pencil, which is black, or nearly black, in the pencil itself, but when a portion of it is rubbed off upon the slate—as happens when you make a mark with it—it is nearly white. In the same manner, iron, when it is seen by itself in a pure and solid state, as, for instance, when you look at the end of a bar which has been broken off, is of a bright bluish color; yet when it is combined with a certain portion of oxygen in rust, is of a dull brown, while yet the oxygen which combined with the iron to form the rust, as it existed in the air before it joined the iron to form the rust, had no brown color, and, indeed, no color at all, but was perfectly clear and transparent. So the substance of water, when it is in the form of water, is liquid, and when in the form of ice it is solid and hard."

"That's because it is frozen," said Flippy.

"Yes," replied Lawrence. "Calling it frozen is only our way of saying that it is cold and hard, but in substance it is only water still, just as it was before. When water becomes of a certain degree of coldness it becomes hard, and, on the other hand, when it is heated to a certain extent, it becomes a gas, thin and completely invisible, and lighter than air. We call it then steam; but it is water still, though it has changed its form and appearance."

"But we can see steam," said Flippy; "it looks like white smoke."

"Very well," replied Lawrence; "but even in that case it has entirely changed its form and appearance, for nothing can be more unlike in appearance, or in what we call sensible qualities, than water when it is in its liquid state, lying quietly and heavily in a bowl, and when it rises into the air in vapor in the form of a white cloud. Then, when it becomes snow, it takes the form of a white powder."

"That's very queer," said Flippy. "I never thought of that before."

"I think it is very curious indeed," said Lawrence.

"So do I," replied Flippy.

"These changes of form are still more remarkable in the case of carbon," said Lawrence.

"I thought that carbon was coal," said Flippy.

"It is," replied Lawrence, "or, rather, some kinds of coal are composed almost entirely of carbon, and coal is black. But we can not say on that account that carbon is black, for these candles here along the table are composed in a great measure of carbon, and they are perfectly white."

Here Flippy drew one of the candles near him, and examined it very closely, in expectation of detecting some very minute black specks in it, but he could not.

"If I had a microscope," said he, "perhaps I could see them."

"No," replied Lawrence.

"Not if it magnified a thousand times?" asked Flippy.

"No," replied Lawrence, "not if it magnified a thousand million times. You could not *see* any thing black there, because there *is not* any thing black there. A thing is black or white, not according to the nature of the substance that composes it, but according to the manner in which the particles are arranged so as to absorb or reflect the light. Now in the candle the particles of carbon in combination with those of hydrogen are arranged so as to reflect the light in such a manner as to look white. In coal they are so arranged as to look black. In the diamond, which is composed almost entirely of carbon, they are arranged so as to allow the light to pass entirely through, and thus to look transparent."

Lawrence then went on to explain the structure of the candle, and the nature of the process of lighting and burning it. His explanation was substantially as follows:

The hydrocarbon of which the candle is composed, whether tallow, or paraffine, or spermaceti, or wax, can only be combined with oxygen in an exceedingly slow and gradual manner, so long as it remains at the common temperature of the air; but when it is heated to a certain point, then the oxygen, if there is any near, seizes upon it with the greatest avidity, and consumes it very rapidly indeed, and with so much violence and intensity of action as to produce great heat and bright light. No one knows at all why the oxygen should act thus so much more powerful at one temperature than another, or why, in so acting, it should give out so much additional heat and light. We know something about the *quantity* of heat and light that is thus developed, as will be presently explained, but very little, with certainty, about the manner in which the action of the oxygen upon the hydrocarbon develops it.

In consequence of this fact, that the oxygen, in combining with the hydrogen and carbon, develops a great amount of heat, it is not necessary to raise the whole of the substance up to the point of combustion to enable the oxygen to consume it all. It is only necessary to heat a small portion of it, for the heat developed by the combustion of this portion will raise the next portion of it up to that point, and that the next, and so on until it is all consumed. This heating of a small part of any hydrocarbon in order that the oxygen may begin to act upon it visibly, and, by so acting, develop heat enough to bring the next portion up to the right temperature, so that it can seize upon it too, is what we do when we light a lamp, or kindle a fire. We set the oxygen at work by heating up a part of its food for it.

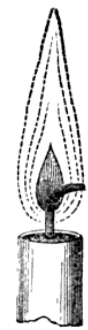
"Cooking it, I suppose," said Flippy.

"Yes," said Lawrence, "you might call it that. If we cook it a little, just so that the oxygen can begin, it will go on cooking, as you call it, the rest for itself—each portion in succession, as fast as it reaches it."

Lawrence went on to explain that this was the way the operation proceeded in the case of the candle. The waiter brings the flame of another candle up and holds it against the wick a moment. This heats a portion of the wick up to the point that enables the oxygen in the air to combine with it. In combining with it, the intensity of the action is so great that the next portion below is heated up to the required degree, and then the oxygen combines with that and develops more heat.

Now, if the wick went down into a candle of stone, or of any other substance which was already combined with oxygen, then, as soon as the projecting part was burned, it would go out. But the candle is formed of a hydrocarbon, and the substance of it has a strong affinity for oxygen when it is raised to a proper degree of heat. But the wick, when it burns down to it, first melts a portion of it, and then draws it up into the fire which is burning in the wick. Here it is heated enough to enable the oxygen to seize it, and, in seizing it, more heat is developed by which more of the wax, or spermaceti, or whatever the substance is of which the candle is composed, is drawn up, heated, and burned. Thus the process is really a very curious one.

As Lawrence explained it in this way to the boys, he told them that by looking at the candle very closely they could see the current of melted material flowing constantly up into the wick, where, of course, it came into the fire, and was heated hot enough for the oxygen of the surrounding air to combine with it, and by so doing develop more heat for melting and heating the next portion.


THE CANDLE FLAME.

The boys looked very intently into the candle to watch the flow of the melted spermaceti as it passed up into the wick. While doing so, Flippy observed one or two little dark-colored motes which were floating in the melted current, and he observed that they went up first till they reached the edge of the flame, and then darted back again, as if they were burned; and after waiting a moment near the outer edge of the candle, they came back slowly, till they touched the fire, when they darted back again as before.

"Oh! John," said he, "look at those little jiggers that keep swimming back and forth. They go up to the fire till it burns their noses, and then they start back and stay away a little while, and then try it again. See! What are they, and what makes them act so?"

Lawrence said that he could tell the boys what they were better than he could tell them what made them act so. He then went on to explain that the cotton of the wick, though formed chiefly of hydrogen and carbon, which the oxygen could consume, contained also some other substances which came from the earth, and which the oxygen had previously consumed—that is, with which it was already combined, and, of course, it could not combine with them again. These substances remain in the form of ashes, he said, when wood, or paper, or cloth, or any other such substance is burned. Even in so small a thing as the wick of a candle there is a certain portion which can not be consumed—that is, which the oxygen can not combine with, because it is already combined with all the oxygen that it can take.

This incombustible portion, or ash, as we call it, in the case of an ordinary fire, remains on the hearth after the fire has burned out—that is, after the oxygen has combined with all the hydrogen and carbon, and formed gases by combination with them, which have gone away up the chimney.

In the case of the wick of a candle, however, especially in candles of the nicer kinds, the particles of their ashes are so delicate and minute that most of the substance of them float away into the air in the form of a fine dust, or are carried up in the current of hot gases which are produced by the combustion of the hydrogen and carbon.

"These little motes that you see," said Lawrence, in completing his explanation, "are generally, I suppose, small portions of the ashes which have fallen down into the melted spermaceti or wax, though they may sometimes be particles of dust of other kinds that were floating about in the atmosphere. But what causes them to play back and forth in that way is a puzzle. I can't tell you, because I don't know."

"Can't you find out?" asked Flippy.

"No," replied Lawrence. "I have watched them very often, but never could understand what was the cause of their moving in that manner to and fro."

"I mean to watch them," said Flippy, "and see if I can't find out."

After hearing all that Lawrence had to say in respect to the philosophy of combustion as exemplified in the burning of a candle, John admitted that it was very curious, and that he was very glad to have it explained to him, but still he contended that Lawrence, in telling them that the waiter was going to perform a chemical experiment in the saloon, had made fools of them, and that he ought to pay the fine for a misdemeanor.

"On the contrary," replied Lawrence, "it seems to me that, instead of making fools of you, I have made you wiser than you were before, by explaining all this philosophy to you."

"That's nothing," said John. "You deceived us, at any rate; you made us think it was something very different from lighting a candle. Besides, we will leave it to Flippy to decide."

Lawrence agreed to this, and so the case was stated to Flippy, and the arrangement was explained to him by which Lawrence and John were to pay into a common fund a fine of five cents for every misdemeanor, and two cents for every peccadillo; and they explained to Flippy the definition which they had agreed to give to these two classes of offenses respectively. They also stated to him that the money was to be spent in an excursion in the environs of Paris when they should reach that city.

"But that won't do *me* any good," said Flippy.

"Yes," replied Lawrence, "we will invite you to go with us on the excursion, if you like."

"Then," said Flippy, "I decide that it was a misdemeanor, and he must pay five cents fine. You see," he added, by way of justifying his judgment, "that we must get all the money we can for the excursion, so as to have a good long one."

"True," replied Lawrence; "but do you think it was any more than a peccadillo—two cents."

"Yes," rejoined Flippy, "it was a misdemeanor—a real misdemeanor."

"Good!" said Lawrence. "I'm glad to have such a strict judge. He'll be more likely to be sharp in deciding against you, John, when it comes your turn."

"But I'm not going to have any turn," said John. "I'm not going to do any misdemeanors or peccadilloes at all."

"Oh yes," said Lawrence.

"No," rejoined John, "I'm determined not to do any thing at all."

"You and Flippy will get to fooling together on the deck," rejoined Lawrence, "and will run against, or disturb the other passengers."

"No," said John, "I'm determined not to do any such thing."

"You will go climbing up the rigging, or mounting up to some other place, where no gentlemen, but only boys, ever try to go."

"No," said John, "I'm determined to keep always in the places where I see other passengers go."

"You and Flippy will get to quarreling with each other, or with the other boys or girls, about your turns at the swing."

One of the sailors had rigged up a swing for the amuse ment of the children among the passengers, by means of rope suspended to a beam, which was extended from the top of the saloon to the bulwarks, over the main deck.

"No," replied John, "we won't quarrel at all. We'll take our turns fairly."

"Well, at any rate, you'll be sure to get engaged in some foolery or other," said Lawrence, "and Flippy is so strict that he will decide against you if you do. We might take Flippy in with us in the plan, if he likes."

"Yes," said Flippy, eagerly, "take me in—take me in."

"And then John will have to be judge if I accuse you of any thing," said Lawrence.

"Yes," said John, "I'll be judge in his case."

"And you must watch each other," said Lawrence, "when I am not by, and I'll be judge in those cases. You see we want to get all the money we can for the excursion."

The boys agreed to this, and, feeling a desire to see how it looked after dark on deck, they went out of the saloon, leaving Lawrence alone. As they walked away, he said to himself, with a smile of satisfaction on his face,

"I don't think I shall actually collect many fines from them, but, on the contrary, shall probably have several to pay myself; but if I can induce the boys to watch each other, and consent good-humoredly to be watched and checked by me in their boyishness, during the voyage, just by being fined myself now and then a few cents for a peccadillo or a misdemeanor, it will be one of the best investments of petty cash I ever made.

CHAPTER VII.

THE FIRE IN THE STREET.

Flippy had not taken any very deep interest in Lawrence's explanation of the philosophy of the burning of a candle, though he had listened tolerably attentively, and had answered pretty well the questions which Lawrence had asked, and had even asked some questions himself, showing that his curiosity on the subject was at least partially awakened. But Lawrence was well aware that in respect to the interest of children in the acquisition of knowledge, as well as to their progress and improvement in all respects, as, indeed, it is in respect to every thing desirable that we wish to obtain from others, to be thankful for little is the best way to get more.

Accordingly, for a few days after this Lawrence said nothing to either of the boys about the philosophy of combustion, or about any other scientific subject, but talked to them, and especially to Flippy, about what they saw around them on board the ship, explaining to them the action and use of all the various fixtures and contrivances which they observed upon the deck and about the rigging. He showed them the boats, eight or ten in number, which were placed along the sides, and pointed out the ways in which they were suspended and secured, so that they should at once be out of the way of the passengers, and safe from the shocks of the seas, and at the same time so suspended by tackles and blocks upon turning cranes, called *davits*, that they could be swung out over the ship's side and let down into the water at very short notice, and in a very rapid manner, in case any accident should happen requiring the use of them.

Some of these boats were bottom upward, and were fully furnished with oars, sails, water-casks, and every thing else which could be required in case of emergency, all carefully lashed in their places and otherwise secured, and protected, moreover, by the bottom of the boat, which served as a roof over them.

He also showed them the compasses, of which there were several along the main deck, and one upon the bridge which led across from one paddle-box to another, for the walk of the captain and the pilot. He also took them both about from place to place, and asked them a great many questions about what they observed, to see if they could find out what the different things were, and what they were for; and when they did not know and could not find out, he explained to them, if he knew, what the thing was or was for, and, if not, he said frankly that he did not know.

"We must ask some of the officers," said John, in one such case.

There were a number of officers to be seen walking to and fro, at their posts, in various parts of the deck. They were known by a kind of uniform cap which they wore.

"No," replied Lawrence, "we must find out in some other way than that. It is against the rules of etiquette on board a steam-ship like this to ask questions of the officers and men while they are on duty."

So saying, Lawrence pointed to an inscription on the brass covering of one of the compasses, saying that passengers were requested not to hold conversation with the officers when on duty.

"But I saw one of the passengers talking with an officer," said Flippy.

"Yes," replied Lawrence, "all such rules have exceptions. He may have been an acquaintance of the officer, and so may have felt himself authorized to speak to him. Or he may have been inconsiderate, or ignorant of the rule, and the officer would not refuse to answer him, not willing to be rude."

"I don't see what harm there could be in any of them just answering a question," said Flippy. "It would not take him but a minute."

"It would only take him a minute to answer one question," said Lawrence, "but he would have an immense number to answer if every body was at liberty to ask them. You see at every voyage they take on board several hundred fresh passengers, nearly all of them very ignorant, and full of curiosity about every thing they see; and if it was understood that they might all ask as many questions as they pleased, the time of the ship's company would be half taken up in answering, over and over again, the same inquiries. And they are under no obligation to do this. What we pay our passage-money for is to be conveyed across the Atlantic, not to be taught the mysteries of the rigging and management of the ships."

John kept a journal. It was a pictorial journal. He pasted pictures in it, such as he could find, that illustrated the scenes and incidents that he met with, and then wrote brief descriptions under them.

When Flippy saw this journal of John's, he said he wished that he had one. If he had thought of such a thing, he said, he would have bought him a book for it in New York. Lawrence told him that if he chose he could begin his journal on separate pieces of paper while he was at sea, and then he could buy a book at Liverpool and paste them in for the beginning of his book.

"But they won't look like the rest of the book," said Flippy, "if they are written on different papers and pasted in."

"Then you can *copy* them in," said Lawrence. "That won't be much trouble."

"No," replied Flippy; "but I haven't any pictures."

"I can give you some pictures," rejoined Lawrence—"enough to last through the voyage. You will not want many till we get to England, for before long we shall probably have rough weather, and then you can't write."

"The tables tremble so every where," said John, "that it is very hard to write now."

"True," replied Lawrence; "but the more energy and perseverance you show in overcoming such difficulties as that, the more merit there is, and the more you will value your journal in time to come."

"But the writing does not look well," said John; "my hand trembles so much."

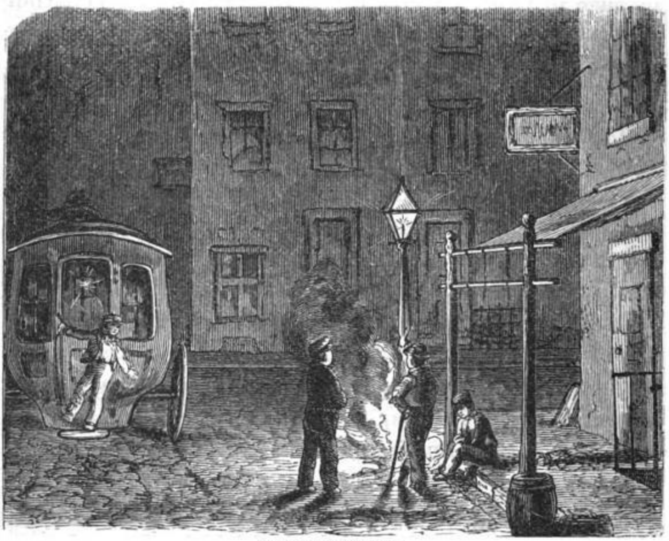
"True," said Lawrence; "but that is no matter. Any badness of writing which comes from carelessness on your part would be disagreeable to look at afterward, because it would be connected with disagreeable associations in your mind. But any tremor in the writing caused by the jarring motion of the ship will only recall the voyage to your mind, and the tremendous working of the floats of the paddle-wheels in the water—which, by striking the water with such immense force and in such rapid succession, cause the jarring—and so will make your book all the more interesting and valuable."

John very readily assented to this view of the case, but Flippy said that if he copied his writing into a book, when he got on land, there would be no jar in the writing. John, however, removed this difficulty by saying that he would stand by the table and joggle it for him, if he wished, while he was writing.

So Lawrence gave Flippy a small picture which he selected from among several which he had laid by for such purposes. It was a picture of some boys making a fire in the street. Or, as Lawrence expressed it, it was a picture of oxygen combining with hydrogen and carbon at a high temperature.

"And I advise you," said Lawrence, "to write those words under your picture as the scientific name of it. You can put with them any additional explanations you choose. It will help you remember what you have learned, and will also show you in after years that at the time when you commenced writing your journal you were also beginning to study science."

Flippy assented readily to this proposal. So he attached the picture, by means of a little gum at the corners, to the top of the paper, and wrote under it the words, as nearly as he could recollect them, which Lawrence had suggested, with some additional explanations of his own—thus:



FIRE IN A STREET.

This looks like a picture of some boys building a fire in the street of a pretty large town, but it is really a picture of oxygen devouring carbon and hydrogen. The boys only heated up a little of the carbon and hydrogen, so that the oxygen could begin. I know that the place is in a pretty large town, because there is an omnibus going along.

When Lawrence saw this work he was very much pleased with it. It is true that the writing was not very good, partly on account of the tremor of the ship, and partly on account of the fact that Flippy, who had never taken much interest in respect to any thing in the way of study, had not learned to write very well. But Lawrence was pleased, because it showed that Flippy had listened, and had, in a measure, understood what he had explained to him in respect to the true nature of combustion; and he felt encouraged to think that he might, perhaps, in the course of the voyage, lead him to feel a considerable degree of interest in acquiring at least one kind of knowledge, and that this might be the beginning of awakening in him a love for other kinds.

At any rate, it was an experiment upon *mind* that he was making, and Lawrence took as great an interest in experimenting upon mind as in watching the operation of causes and effects in the material world.

Lawrence did not openly praise Flippy's work when it was shown to him, but Flippy saw very clearly that he was satisfied and even pleased with it. This greatly encouraged him, and made him quite ready to undertake any thing new which Lawrence might propose. He was, however, somewhat disconcerted at the result of showing his production to his mother. He took it to her when she was sitting on the deck, under the shelter of one of the paddle-boxes, in company with one of her fashionable friends, both being well wrapped up in cloaks and mufflers. Mrs. Gray looked at the picture a moment, read what was written under it, and then, holding it so that the other lady could see it, she said,

"The picture is pretty enough, isn't it, Maria? But then the writing!—I'm quite ashamed of Flippy's writing. I really believe I shall have to change his school. He does not seem to improve in his writing at all."

She proceeded to read what Flippy had written, aloud, to her friend, and then asked Flippy who told him to write such things as that. Flippy said it was Mr. Wollaston.

"Well," said she, handing him back the paper, "it may be all very well for what I know, but it seems to me to be only learned nonsense." Flippy took his paper and went away quite disconcerted. He resolved that after that he would show all that he did to Lawrence, but no more of it to his mother.

CHAPTER VIII.

THE THREE RECAPITULATIONS.

ONE morning, a few days after this, when Lawrence and the two boys had been on the quarter-deck together watching the operation of heaving the log at four bells—that is, at ten o'clock—and had then taken their seats together on one of the settees on the deck, which were placed alongside the skylight, Lawrence told Flippy that he thought what he had written about the Fire in the Street, when copied handsomely in his journal, would make a very good beginning for it.

"And what you said in it of your own accord," he added, "gave a very good account of the substantial nature of combustion. You *expressed the principle* very well indeed, and very correctly, and it shows that you paid attention to what I explained to you about it, and that you understood it very well."

Flippy was much pleased with the idea of his having been able to "express a principle."

"I don't know," continued Lawrence, "but that you and I might make a recapitulation of all I have taught you on the subject."

"Well," said Flippy, in a tone of alacrity and pleasure, "we'll do it."

He had no idea at all what a recapitulation was, but he thought it sounded as if it was something that he would like to make, if he could.

Lawrence explained to the boys that to make a recapitulation of any instruction or information you have received is to state the substance of it, as you understand it, in your own words, in the best way you can. He then added:

"I'll tell you what—I have a plan to propose. I will explain once more what I have told you about the grand part that oxygen plays in all the changes taking place in nature, and we will all three write a recapitulation of the principles; and the one that writes the best one shall have a prize. I will buy the prize when we get to Liverpool, and it shall be given to the one who writes the best recapitulation."

"Ah! but that won't be fair," replied Flippy. "Of course you can write the best one. I never wrote a recapitulation in my life. Even John can write a great deal better one than I can."

"Yes, but we will make allowance for our different ages and abilities," said Lawrence; "it shall be a kind of handicap."

The boys did not either of them know what a handicap was. Lawrence explained to them that it was a term used in racing, and that it denoted an allowance made for the several horses on account of the difference between them in respect to certain conditions which would affect the result of the race. The allowance was made in order to give each one as nearly as possible the same chance in the trial.

"We will have the major for umpire," said Lawrence, "and he shall make the allowances for our different ages and capacities; so that he will have to decide, not which is absolutely the best recapitulation, but which is the best *for the one who wrote it*, considering his age and his opportunities for learning."

"Agreed!" said John; "but what shall the prize be?"

"Something that I will buy in Liverpool," said Lawrence, "when we arrive there. I will get you a little compass, or a pencil-case, or something like that."

Flippy said he should prefer a compass. He had wanted a little compass, he said, ever so long.

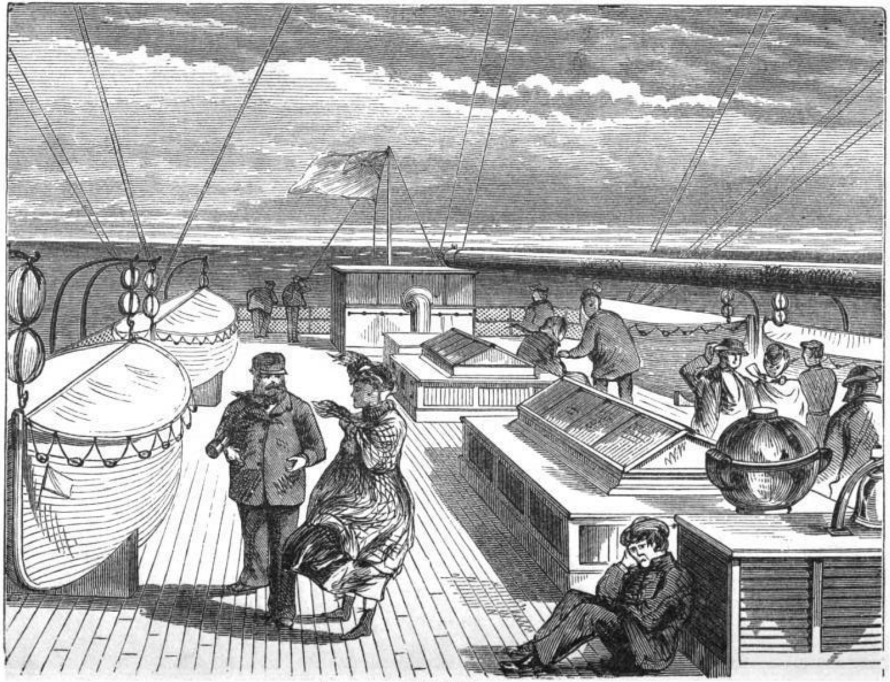
"But then," he added, somewhat mournfully, "I don't suppose there is much chance for me to get the prize."

"We can't tell," said Lawrence. "The major will make full allowance for your being the youngest, and not having had much experience in such work."

The arrangement having been thus made, Lawrence explained again to the boys, in the course of several conversations which he held with them during that and the following day, what he had already told them about the agency of oxygen in the great revolving cycle of change that was going on incessantly in nature in connection with the principle of life—how that in some mysterious way the sun, by a wonderful power inherent in its beams, separates the two great elements, carbon and hydrogen, from their combination with oxygen in the air, and in the moisture which floats in it, or which is drawn up by the rootlets from the ground; how these substances are held thus beyond the reach and power of oxygen in the tissues of plants—and in the tissues of animals when the plants are eaten by animals—so long as the principle of life continues; and that at length, when this ceases to protect them, the oxygen takes possession of them again.

The oxygen, moreover, as he farther explained, recovers possession of these substances by slow degrees and in a very gentle manner, so long as they are kept at the ordinary temperature of the air; but very rapidly, and with the most intense and violent action, when they are raised to a certain degree of heat. But, in whichever way it recovers possession of them, it carries them off in gases into the air, and in water into the ground, and keeps strong hold of them, until at length the sun, by his mysterious power acting in the leaves of plants, recovers them, and converts them again to the purposes of vegetable life, whence they afterward, when released from this protection, are seized again by the free oxygen floating in the atmosphere, or mingling with the portion of air which is generally contained in water, till they are again separated from it, in fresh leaves, by other beams from the sun; and so the change goes on in an eternal alternation.

Lawrence ought to have explained to the boys, if he did not, that what he had taught them was only a *very general* view of the great leading principle which governs the phenomena of life on the one hand, as revived, sustained, and perpetuated upon the earth through the instrumentality of the sun in deoxydizing carbon and hydrogen, and of death, decay, and combustion as a reoxydizing process. This is, indeed, a great leading principle, and one which it is very important that all students of nature should understand, for it is a fundamental one, and the knowledge of it aids us very much in all subsequent studies, and assists us more clearly to comprehend and to systematize in our own minds the other truths and principles which we may learn. But this principle, though a fundamental one, is only a *general* one. In its actual operation it is involved in an endless number of complications and details, in which a vast variety of substances are formed, and after fulfilling in the most various ways their several curious functions, are dissolved and disappear, while the elements of which they are composed enter into new combinations, form new substances, which fulfill new functions, and then dissolve and disappear as their predecessors had done, and so on in an endless maze which it is utterly impossible that any human intelligence should ever fully unravel. As we advance in the exploration of this field, the more we learn and the more we know, the more glimpses we obtain of mysterious complications beyond.



ON DECK.

Lawrence had explained the general principle to the boys before, but when the plan was proposed of writing recapitulations for a prize, he explained it again in a somewhat more simple manner than I have done, and with many references to common facts respecting the *sun* and *life* as deoxydizing, and *decay* and *combustion* as reoxydizing agents. He also used the terms hydrogen, carbon, and hydrocarbon very frequently and familiarly, so as to accustom the boys to them, and to associate the meaning of them with the sounds in their minds.

After having in this way made the subject as plain as he could to the boys, he made the arrangement with them that they should write their recapitulations the next day before dinner, and then refer them to the major for his decision between dinner and tea. Lawrence told the boys that they need not undertake to write a great deal. It was only a brief statement of the general principles that was required.

John and Flippy determined to write their recapitulations upon the deck, where they could look out occasionally over the water while they were writing, to see if any ships, or whales, or icebergs came in sight. Lawrence wrote his in a small place, like a room, below, which was called the gentlemen's cabin, and which contained a large table, with seats. They all finished their work before luncheon, which was at noon; but, as the major seemed to be engaged with other gentlemen after luncheon, they concluded to wait until dinner-time before they mentioned the subject to him, and then to ask him if he was willing to act as umpire, and, if so, if it would be convenient for him to hear the articles which had been written, and decide which was the best, between dinner and tea.

This arrangement was accordingly made; and when the tables had been cleared after dinner, they all four went to the end of one of the long tables, at the farther part of the saloon, where they could be together and be undisturbed.

"Well," said the major, as soon as they were seated, "what is the business before this meeting?"

Lawrence stated the case, saying that they had agreed to write, for a prize, a recapitulation of the principles which lay at the foundation, in a chemical point of view, of the great alternation and rotation of life, death, and decay, and that they wished him to hear what had been written, and decide, as umpire, which of the writers deserved the prize.

"H'm!" said the major, if making the inarticulate sound represented in that way can be called *saying* any thing. "It seems to me that the boys have hardly a fair chance with you, Lawrence, in such a contest as that."

"Ah! but you see it is a kind of handicap," said Lawrence. "You are to make allowances."

"Oh! A handicap, is it?" rejoined the major.

"Yes," replied Lawrence; "you are to make proper allowances for differences of age and opportunities for instruction. The question is not which statement is absolutely the best, but which is the best considered as a performance of the one who made it."

"Very well," said the major; "that makes it all right. So go ahead with your reading. I shall not be long in deciding after I have heard the documents. We will hear Flippy's first, as he is the youngest."

So Flippy began at once, and read his paper as follows:

RECAPITULATION.

BY

PHILIP GRAY.

Oxygen is something that you can not see by itself. It is in a great many things. You can see the *things*, but you can not see the oxygen.

It has a great appetite for a great many things. They call the appetite a finnity. The principal things it likes best are carbon and hydrogen; but it can eat even into iron.

The sun gets the carbon and hydrogen away from the oxygen somehow or other in the leaves of plants when they are growing. It keeps the carbon and hydrogen, and makes hydrocarbons of them, and turns the oxygen off loose.

By-and-by the oxygen finds the hydrogen and carbon, and eats them up again. If they set the things on fire, the oxygen eats them up very fast, and makes a great blaze.

Here Flippy finished his reading, and looked up to see how the major seemed to have taken it.

"Good!" said the major. "Now hand me the paper and let me look at the writing."

Flippy gave the paper into the major's hand, and the major cast his eye over it. He observed that Flippy had taken pains to write as well as he could, and that the lines were even and the letters well formed, so far as the tremble of the ship would permit. He observed, it is true, that the word *affinity* was spelled *a finnity*, but he said nothing about it.

After the major had returned the paper, John, who had looked over Flippy while he had been reading it, remarked that there was one fault; he had spelled the word affinity wrong.

"Did you tell him how to spell the word?" asked the major, looking toward Lawrence.

Lawrence said he did not.

"Then how should he know how to spell it?" asked the major. "I think that is no fault at all—that is, I mean, no fault of Flippy's. Now, John, let us hear yours." So John read as follows:

ABOUT OXYGEN.

The most common thing in the world is oxygen. Oxygen is not a thing exactly, but a kind of substance out of which a great many things are made. It is an *element.*

When it is obtained by itself it is a gas which may be kept in a glass jar. Almost any thing that is put in it and set on fire burns furiously.

It has a great affinity for almost all substances, and when they are only moderately warm it dissolves them, or combines with them slowly. When they are very hot it combines with them very fast and very furiously, and gives out heat and light. This is what we call *combustion.*

The oxygen that there is in rocks, and sand, and gravel is already combined with other substances—enough to have its fill—and so it lies quiet. So it is with the oxygen which exists in the water of the sea, and of lakes and rivers.

But the oxygen that is in the air is free, and it goes about trying to find something to devour. It devours all the dead leaves and dead wood in the forests, and all the dead bodies that are left on the ground. It even gnaws into iron, and so they call it a great devourer.

This was the end of John's recapitulation. It then became Lawrence's turn. He opened his paper and commenced as follows:

LIFE AND OXYGEN;

OR,

THE ECONOMY OF NATURE IN RESPECT TO THE ROTATION OF LIFE, GROWTH, DEATH, AND DECAY.

1. The substance which takes precedence of all others in the economy of nature, as observed by man, on the surface of the earth, both in respect to its abundance as to quantity, and to the extent and importance of the functions it fulfills, is oxygen.

2. Oxygen has a very strong affinity for most other elements. It combines with them with great readiness, and sometimes with great avidity, and holds them in combination with great force. It may be called the great *strong-holder* of nature. There is another remarkable substance, which may be called the great *weak-holder;* but, as I have not yet described this weak-holding substance to the boys, I do not bring it into this recapitulation.

3. The power of the sun, as transmitted to the earth in its radiations, and acting in connection with the principle of life, is the great antagonistic force with which oxygen has to contend.

4. The power of the sun, in taking substances away from their combinations with oxygen, is exercised chiefly in the leaves of plants, while the plants are growing.

5. The two chief substances which it thus takes away are carbon and hydrogen. It takes the hydrogen from the water which comes up from the ground through the roots, or floats around the leaves in the air; for this water is composed of oxygen and hydrogen. It takes the carbon from a certain substance called carbonic acid, which exists in small quantities both in water and in the air, and which is composed of oxygen and carbon.

6. The hydrogen and carbon, thus forcibly separated

from the oxygen with which they were combined, are formed into vegetable tissues or vegetable substances, which remain in the plants, or, when the plants or portions of them are consumed by animals as food, pass into the animals, and are modified there in various ways, being protected all the time while they remain parts of the living system from being taken by oxygen again.

7. At length, when the plant or the animal dies, or when, before they die, any portions of these substances are rejected from the living organization, so that the carbon and hydrogen are no longer protected by the principle of life, the oxygen floating in the air claims them again, reunites with them, and thus reconstructs carbonic acid and water with them, and in this form carries them away. When the oxygen recovers these substances by a slow and gentle action, as it does at ordinary temperatures, we call the process *decay*. When the process is rapid and violent, as it is when the action is commenced by the application of a certain degree of heat, and is accompanied by the development of light and heat produced by the intensity of the force with which the combination takes place, it constitutes what we call *combustion*.

8. In whichever way the oxygen recovers possession of the carbon and hydrogen, it carries these substances off in the forms of carbonic acid and water—which it produces by combination with them—to float about in these forms in the atmosphere, or to be absorbed by the ground, until the sun again seizes them in the leaves of growing plants and recommences the same never-ending round.

9. Thus the general principle which governs the great movement of life and growth on the one hand, and, on the other, of death and decay, which follow each other in an endless procession in the economy of nature on the surface of the earth, is that of the deoxydation of carbon and hy-

drogen by the power of the sun, in connection with the principle of life, in the leaves of plants, and the reoxydation of them after death by a rapid and violent action in combustion, or a slow and gentle one in decay.

"That's the end," said Lawrence, looking up from his paper after he had finished the reading of it.

"Yes, I think it ought to be," said the major. "It is good enough, but it is too long. And now as to the boys. I must ask them some questions, so as to know what allowances to make. Did you ever study chemistry, Flippy?"

Flippy said he never had studied it at all. He did not even know, he said, what chemistry was.

"And did you know nothing about all this," asked the major, "till Lawrence explained it to you on this voyage?"

Flippy said he did not.

The major then asked John the same question. John said that he had studied chemistry at school, and had heard a course of lectures, and had even performed some experiments, but that he had never heard before what Lawrence had explained to him about oxygen and the sun.

"Then I think," said the major, "that in respect to the prize, the question is between you and Flippy. As for Lawrence, he is nowhere. His article is nothing for him, with all the study he has had at the scientific school, compared to what either of yours are for you. And, besides, his is too long. It is an essay rather than a recapitulation. As to yours, boys, they are so nearly equal, judged on the handicap principle, that I can't undertake to distinguish between them, and so I decide that Lawrence must give you both a compass when we arrive at Liverpool."

The boys were both well satisfied with this decision, but they were neither of them better satisfied with it than Lawrence was.

CHAPTER IX.

ENORMOUS FORCE.

The force transmitted to the earth from the sun, and which acts in the leaves of plants in the manner described in the last chapter, comes in three different forms or kinds of rays, namely, rays of light, of heat, and of chemical force. The scientific names of these three kinds of emanation are,

1. The luminous rays.
2. The calorific rays.
3. The actinic rays.

They are sometimes, however, designated simply as *light*, *heat*, and *actinism*.

It is very possible that some of the readers of this book may never have heard of this last-named kind of rays, namely, the actinic rays, and, if so, I advise them to pause here long enough to fix the word in their memories; for the word, uncommon as it is in ordinary discourse, is used a great deal in the scientific works that you will read as you grow older, and it denotes, moreover, a very important thing. It is, for example, chiefly by the power of the actinic rays, or the *chemical* rays, as they are sometimes called, that the image is fixed upon the sensitive paper in photography. It is commonly said that the image is fixed by the *light*, which is not strictly true. This mode of speaking arises from the fact that the luminous rays and the actinic rays come nearly together in the same beam, and so people generally, not distinguishing between the two, and perhaps not knowing that there is such a distinction, call the whole radiation *light*, that being a convenient term, and one with which every body is familiar.

The photographers, I think, generally call the actinic rays the chemical rays, for it is by the chemical effects which they produce that they are chiefly known to us. It is by a chemical effect, produced on the sensitive paper in photography, that the picture is produced.

As to the word *actinic*, a very good way to fix it in the memory is the one which Lawrence adopted with John and Flippy in helping them to remember new and difficult words, which was what he called *running them over the tips of the fingers.* He said that a very excellent way into the memory was by the tips of the fingers. The method of impressing the word upon the memory in this manner was as follows: The boy, with the forefinger of his right hand, would touch the thumb of his left hand, speaking at the same time, in a very distinct and emphatic manner, the word *actinic*, or the word, whatever it might be, that he wished to fix in his mind. Then he would touch the tip of the *forefinger* of the same hand, and pronounce the word again, and so on with all the fingers of that hand in succession.

He would then proceed in the same way with the thumb and fingers of the right hand, touching them with the forefinger of the left, and pronouncing the word *actinic* very distinctly over every one. In this way he would pronounce the word ten times, and this would be, in most cases, a very effectual means of familiarizing him with the sound of it and fixing it in his memory. I advise the readers of this book to try this plan with any new and difficult word which they wish to make themselves remember, commencing, if they please, with the word actinic, or actinism.

All the three kinds of radiation which have been described above mingle in their action on the leaves of trees and plants when the sun is shining upon them. What special part each one takes, and in what precise way they severally act, in forcing the hydrogen and carbon from the oxygen, is very imperfectly understood; but one thing is certain, and it is a very curious and important thing to understand. It is this:

That the radiation from the sun produces its effect of separating the oxygen from the carbon and hydrogen by the exercise of a certain amount of *force*, and that this force—precisely this amount; just so much and no more—is imparted to the vegetable substances produced, and remains in them in a state of suspended action, as it were, to be given out again in the form of heat, or in some other form, when, in the process of combustion or decay, the carbon or hydrogen fall back into the possession of oxygen again.

In other words, the force by which a particle of hydrogen is separated from the particle of oxygen in the leaf, to help make of it a hydrocarbon in the plant, is stored up in the plant, and precisely that amount comes into action when afterward the particle of hydrogen is again united to a particle of oxygen.

Just as when the string of a bow, in a bow-gun, is drawn back and hooked over its peg, the force with which it was drawn is *stored*, so to speak, and retained, and remains in a state of tension and suspense until the string is released, when precisely that amount—no less and no more—is given out and expended in impelling the arrow.

This effect of the sun's radiation in storing up, so to speak, a definite and precise amount of force in the tissues produced by vegetation, is one of the great scientific discoveries of modern times. Lawrence explained it to John and Flippy. Flippy said that, after all, he did not understand it very well, on account of there being so many hard words. Lawrence told him that he could, at any rate, understand it in this form, which was the common mode, he said, of explaining it—namely, that the heat from the sun which comes in through the leaves of plants is stored up in the wood in the form of *a force in a state of tension;* that it remains in the wood, and in the coal into which the wood becomes transformed when buried up deep in the ground; and that this force is set free when the carbon and hydrogen again fall back into the power of oxygen, as they do with great rapidity and violence when the wood is burned.

"And if you like," continued Lawrence, "we will go down into the engine-room some day, and see the furnaces where the firemen are at work delivering up the carbon and hydrogen of the coal to the oxygen again, and so making it give out again its store of force to work the engine, and drive the paddle-wheels, and so carry the ship, and all of us who are on board, across the Atlantic Ocean."

Flippy said that he should like to go very much, if they would let him.

"I will see the engineer and ask him," said Lawrence. "I believe he likes to have people go down and see the machinery, for they generally give him a little fee when they come up, to spend for the benefit of the men."

One morning, about an hour after breakfast, the two boys were sitting on the narrow seat in the state-room, eating each an orange. On board these steamers you can have as many oranges as you like by just asking a steward to bring them. While thus engaged, they heard the voice of one of the passengers, from one of the state-rooms near, calling to a steward along the passage. The steward answered, "Coming, sir," and immediately afterward the boys heard the following conversation:

"What o'clock is it, steward?" asked the passenger.

"Ten minutes past ten, sir," said the steward.

"My soul!" exclaimed the man. "Just a good time for me to lose my breakfast."

"It *is* rather late for breakfast, sir," said the steward.

The custom is to serve breakfast from eight, or half past eight, to ten, during which time the passenger can order any thing that he pleases, as at the great New York hotels, and the cooks will prepare it for him at short notice. But after ten it is too late. The cooks and stewards then are all busy in preparing for luncheon, which is to be on the table at twelve; and as, in crossing the Atlantic from west to east in a swift steamer, there is only about an hour and a half between ten o'clock and noon, and as, moreover, there are usually some hundreds of passengers to be provided for, it is evident that they have no time to waste on those who are too indolent to be ready for breakfast in season.

"But I must have something for breakfast," said the man. "I shall die if I can't get any thing to eat."

"We can give you a cup of tea, sir," said the steward, "and a slice of cold meat, but it *is* rather late to order any thing hot."

Just at this moment Lawrence appeared at the door of the state-room, and told the boys that he had made arrangements with the engineer for them to go down and see the engine, and that they were to go immediately. So the boys threw their orange-skins out through the port into the sea, and then, after wiping their fingers on a towel, they followed Lawrence to the deck.

They proceeded at once to the place near the middle of the ship where the engine, and what pertained to it, and to the engineers, were situated. There was a large opening through the deck, twenty or thirty feet square, guarded by a massive brass balustrade. Looking down into this opening, the boys could see the ponderous machinery moving with prodigious force, the immense cranks on each side rising and falling alternately, and carrying around the main shaft, which passed out through the ship's sides, and revolved the vast paddle-wheels attached to the outer ends of them, by which the steamer was driven through the water with such tremendous force. Some of the innumerable bearings of the machinery were oiled by a self-acting apparatus—a little pin in the wheel at each revolution opening the passage-way and allowing a small portion of oil to flow out. But one great junction—the one in which the monstrous iron beams worked by the cylinders below grasped the crank and carried it round—had to be oiled by a man who stood leaning over the balustrade, and poured a little oil into a brass box over the joint from an elegant long-nosed and highly-polished brass oil-can. The boys wondered at the dexterity of the man in pouring the oil into the box at the right instant as it came up, and then suddenly withdrawing his can just in time to save it from being knocked out of his hand by the immense beam as it went over.

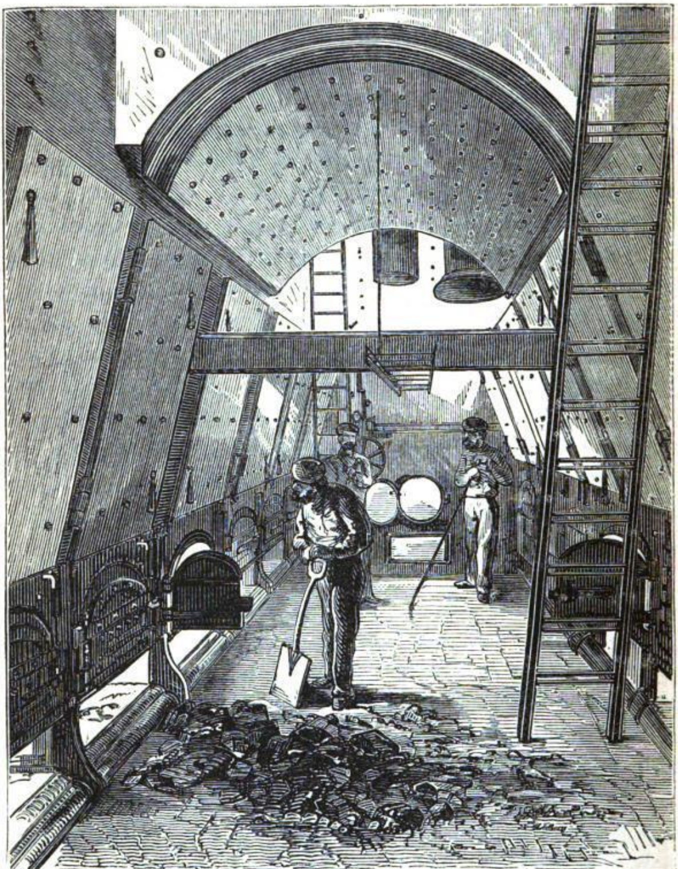
Looking down over the balustrade, they could see a moving mass of ponderous machinery extending through *three stories* below, with floors of open iron work forming galleries between them. There was a very curiously constructed iron stair, very steep, which led down among all this mechanism. Away down at the bottom there was a glimpse of many fires seen dimly through the moving machinery, and of half-naked men shoveling coal into them.

In the rear of this opening on the deck was a large inclosed space covered with a floor formed of an iron grating, in the middle of which was a round opening like a small well, at which four or five men were at work attending to the bringing up of ashes and cinders from the fires below. These waste products were brought up in iron buckets nearly as big as barrels, which were raised by a small engine near, driven, doubtless, by power derived from the main engine. They seemed to come up from a great depth. As soon as one came to the surface, it was seized by two men standing near, unhooked in an instant, an empty bucket which stood ready was hooked on, and at the same instant the two men, bracing against each other for mutual support in sustaining so heavy a weight, hurried off with the full bucket to the side of the ship, and emptied it through an iron shoot into the sea. They then carried the bucket back to the well in time to take the next full bucket as soon as it reached the surface. There was a fifth man in the gang, whose duty it was to attend to the little engine, and shift the movement according as the action of the engine was required to bring full buckets up or to let empty ones down.

The boys had no time for stopping to look at these things, but could only glance at them as they passed in following Lawrence to the engineer. This was, however, of no great consequence, as they had often watched these operations before.

Immediately forward of the great opening through which the machinery was seen there was what in a city would be called quite a little "block" of state-rooms belonging to the engineer's department. They were arranged in two rows, with a passage-way between them. They were for the use of the engineer and his assistants, and had each its own proper inscription in gilt letters on the door. The boys found the chief engineer in his own room, which was a very pretty and nicely-furnished cabin, with a berth, a sofa, a desk for writing, and shelves containing books and scientific instruments. It presented the appearance, indeed, of quite a charming little study.

The engineer, after showing the party his room, led the



A FURNACE ROOM AT SEA.

way onward through the passage-way between the state-rooms to a winding iron staircase, which led down in a much more convenient way than that afforded by the step-ladder already referred to. It would be impossible to convey, by description, any adequate idea of the bewildering maze of mechanism which presented itself to view on all sides as the party descended to the several successive floors. They went down flight after flight of iron stair-way, and walked around in galleries consisting of floors of iron open-work, and bordered by iron balustrades. The machinery was so massive and ponderous, and all its movements were so deliberate and grand, as to give the observer the idea of resistless force, while yet every thing moved with a smoothness and gentleness denoting the utmost delicacy of finish in the mechanism. The jar which is felt in the motion of side-wheel steamers is due, not to any thing like jolting in the machinery, but to the floats of the paddle-wheels striking the water with such great force and in such rapid succession.

At length the party reached the lower floor, where the boilers and furnaces were. There were ten of these furnaces in each row, making forty in all! On the iron floors in front of them were heaps of coal which the men were incessantly shoveling into the mouths of the furnaces, which mouths looked like so many fiery ovens whenever the men opened the iron doors to shovel in more coal. The men were very thinly clad; some of them seemed almost half naked. Of course the work which they had to perform, notwithstanding every thing that could be done to promote ventilation, subjected them to the endurance of great heat.

"You see what they are doing," said Lawrence. "They are delivering carbon and hydrogen to oxygen to be devoured."

Lawrence had to draw very near to the boys, and to speak quite loud, on account of the roar of the furnaces and the other sounds which filled the air.

The men who had charge of the furnaces were incessantly at work opening the doors and shoveling in fresh coal, and seemed to be urging the fires to the highest possible intensity. The fires burned very fiercely, too, as if blown by some invisible bellows—as they were, in fact—the combustion being urged to the utmost by the strong current of air produced by the draft in the two immense chimneys.

After remaining in the furnace-rooms a few minutes, the party set out on their return, and, as they ascended the several staircases and walked along the galleries of the several stories, the engineer pointed out to them the most remarkable and conspicuous parts of the engine. They were particularly struck with the magnitude of the cylinders, and the prodigious force with which the piston-rods were alternately forced up and then down into them again.

The cylinder, as probably most of my readers know, is the *heart*, as it were, of the steam-engine, being, in respect to the action of the mechanism, the central, and, in some respects, the most essential element of it; for it is within the cylinder that the great force of the steam is exerted, and its great work done in driving first up and then down the piston which plays to and fro in the interior of it. The cylinders in the Scotia, the engineer said, were one hundred inches in diameter, and twelve feet stroke. If you measure off upon the floor a length of one hundred inches—that is, about eight feet and a half—which you can do accurately enough by taking about four or five ordinary steps, and then imagine an immense iron hogshead with straight sides to stand on a bottom of that diameter, and to rise to twice the height of a tall man's head, you will obtain a pretty just idea of the size of one of these cylinders. If then you imagine that there are two of them in the Scotia's machinery, and that such a volume of steam must pour into them from the boilers that each may be filled and emptied as often as *once in a second*, you can easily understand with what enormous rapidity the steam must be generated, and will be less surprised at its requiring forty furnaces to produce it.

At length our party came out upon the deck again. Lawrence gave the engineer a generous fee for the benefit of the men in his employ among the machinery and at the furnace below. The engineer invited them to go again into his state-room, and then, sitting on the little sofa, they had ten or fifteen minutes' conversation with him about the engine and about other subjects.

Lawrence informed him that he had read somewhere that, notwithstanding the high degree of perfection to which machinists had attained, in modern times, in the construction of engines, it was, after all, only about *one tenth* of the actual power developed by the combustion of the coal used that was really made available for useful work in the best engines, and he asked him whether that accorded with his ideas and experience.

"Well," replied the engineer, "I should think that that might be about the way they would put it in the books. There is a great deal of waste. There is a great part of the coal that goes off up the chimney in smoke without being burned at all. Then we have to heat up such a great quantity of air to make a draft. Then a great deal of heat escapes from the boilers and the machinery out through the sides of the ship into the water, and from the smoke-pipes into the air. It is not a large portion, after all, of the heat which the coal produces, or might produce, that we get the benefit of in making steam."

The engineer did not confine his conversation to the subject of the engine during the time that the party remained in his state-room, but told them about Scotland, where he lived, so far as one who spends most of his life in sailing to and fro across the Atlantic can be said to live any where on land. He related to them several anecdotes illustrative of Scotch ideas and manners, especially those of the country people, who lived in lonely districts among the Highland glens. He told of one aged Scotch woman, who attached great value to a knowledge of the art of spinning linen thread by means of a distaff and spindle, as practiced when she was a child, before steam and machinery had suspended these primitive modes of labor. "There are a great mony puir bargains for the yoong men noo-a-days in respect of lassies," she said, "for there are noombers of them flaunting aboot, and thinking themsels very bonnie, and but dinna ken how to dhraw a thread."

At length Lawrence and the boys bade the engineer good-by and took their leave. It was now nearly time for the luncheon-bell to be rung, for Lawrence found, by looking at his watch, that it was half past eleven, and twelve o'clock, which was the hour for luncheon, comes very close upon half past eleven on board so swift a steamer as the Scotia when she is sailing toward the east to meet the sun. As, however, the boys passed the place where they could look down through the great opening through the deck to the engine-room, they stopped a moment to look once more at the massive and ponderous machinery, and to observe the wonderful force with which the immense iron beams on each side rose and fell in turning the crank upon the shaft which carried the paddle-wheels.

"I see," said Flippy; "these great bars coming up and down turn the crank and work the paddle-wheels in the water just as I would turn a grindstone by the handle."

"Exactly," said Lawrence; "only there is a slight difference in the degree of power. You would turn the grindstone by a *one-boy power*, whereas the engines carry around this shaft with a *five thousand horse power*."

"A five thousand horse power!" exclaimed John.

"So the engineer told me," said Lawrence. "He said that that was the force *indicated*. He meant by that, I suppose, that that was the amount of force which it was necessary to develop in the steam. Only a portion of it, however, can be really made available in the propulsion of the ship."

"What a big team five thousand horses would make!" said Flippy."

"It would indeed," replied Lawrence. "Few people have any idea of the immensity of the force which it is necessary to develop in working one of these ships. These engines, as the engineer said, 'indicate,' as they term it, five thousand horse power; and that number of horses, if placed tandem, would make a line eight miles long, allowing eight feet in length for each horse and harness. Of course it would be impossible to combine the strength of so many horses in any way, least of all in harnessing them tandem. But if they were placed four abreast it would make a team two miles long, so that we are being impelled through the water by all that can be used of a force equal to a team two miles long and four horses abreast. And all that force is developed by the intensity of the action of the oxygen combining with the carbon and hydrogen in the coal. The oxygen devours the coal at the rate of more than a hundred tons per day! five times as much every day as is required by many a family in New York for their whole winter's supply.

"And what is most curious about it," said Lawrence, "and almost inconceivable, is that this force—as much as would be exerted by five thousand horses—is only about one tenth part of the force which the amount of coal which they burn really contains, inasmuch as nine tenths of it is wasted, or employed in producing the draft; so that the force which they really deal with, it would seem, is that of *fifty thousand horses!*"

"What an enormous quantity of coal they must have on board," said John, "to use one hundred tons a day!"

"They fill the bunkers up every voyage," said Lawrence, "and the bunkers hold eighteen hundred tons. So you see what an enormous weight they have to carry."

"And then," continued Lawrence, "that is not all. There is something else that they require for the voyage that amounts to a great deal more, in respect to weight, than even the coal."

"What is it?" asked John.

"Guess," said Lawrence.

"The provisions," said John.

"No," replied Lawrence; "the provisions would not probably weigh more than a tenth part the weight of the coal."

"The ballast," said Flippy.

"No," replied Lawrence, "not the ballast. Something even more important than that."

"Then I give it up," said Flippy.

"It is something of the greatest possible importance," said Lawrence. "Without it we could not get along at all. And there is a great deal more of it in weight to be taken on board, infinitely more in bulk, than there is of coal."

"What is it?" asked John.

"The oxygen," said Lawrence.

CHAPTER X.

TRACKS OF THE STEAMERS.

Both John and Flippy were very much surprised, as perhaps some of my readers will be, to learn that the amount of air necessary to contain the quantity of oxygen that is required for the combustion of the coal in the furnace of a sea-going steamer—and it is the same, moreover, with any common fire—so far exceeds in weight the fuel that is burned. They will, perhaps, be still more surprised to learn how enormous the excess is. The most careful experiments have been made to determine the ratio, and it is found that no less than *seventy-two* tons of air are required for every ton of coal, to effect the complete combustion of it!

When Lawrence stated this to the boys in conversing on the subject some days after they went below to see the engines, they could hardly believe it. John said he did not see how it could be.

"I can not positively prove it to you," replied Lawrence, "but I can make some computations with you some day to show you how it can very possibly be. As for the actual fact, we have to take the testimony of the scientific men who have made the experiments; but the calculations which I can make with you will show that something like that quantity must be necessary, and so will make the result of the experiments not improbable."

John said that he should like to see the computation. As for Flippy, he asked whether computation was any thing like arithmetic. Lawrence replied that it was a kind of arithmetic. Flippy then said that he did not care about it. He said he did not think it was of any consequence how much air it took, since they found a plenty of it all along the way, and they could have as much of it as they pleased without its costing any thing.

"It seems, however, on the contrary," said Lawrence, "that it does cost them a great deal, for a large part of the coal which they burn is employed in heating up the air in the chimneys, as the engineer said, to make a draft, as a means of bringing the air into the ship and into the furnaces."

This is true, and it is a very important thing to be understood. The attention of visitors to such ships, and also of the passengers on the voyage, is often drawn to the curious shapes of the ventilators and wind-sails which are seen here and there rising up out of the deck. The ventilators are made of copper, and are of the form of immense speaking-trumpets, with mouths as large as the open end of a hogshead, turned always toward the wind, whichever way it blows. The wind-sails, though made of sail-cloth, have a somewhat similar form. The lower parts consist of long cloth tubes, as large round as a barrel, and extending through openings in the deck down to the lower regions of the hold. At the upper end of each of these contrivances, which usually reaches high above the deck, there is a wide opening on one side, which is always turned toward the wind. This opening has two wings, one on each side, which are drawn out and fastened by cords attached to some part of the neighboring rigging. They look, on moonlight nights, like so many ghosts having their arms stretched out and tied, while they are struggling furiously in the wind to get free.

These ventilators and wind-sails—the upper portions of which are seen rising into the air at different places along the decks, the lower portions of them passing down through various openings to the regions below—are so many pipes for the conveyance of oxygen to the furnaces, to maintain the combustion of the coal, as well as also to supply what is necessary for the respiration of the men; for there is a process very analogous to combustion going on all the time in the lungs and in the tissues of the body, in men and animals, and this makes it necessary that a supply of oxygen should be brought in for the breathing of the men as well as for the blast of the furnaces. It is only, however, a very small portion of the whole amount brought into the ships that is required for the men; almost the whole is required for the fires. This portion, being brought down by the ventilators into the furnace-rooms, is then drawn into the mouths of the furnaces by the draft in the chimneys; and if seventy-two tons of air are required for every ton of coal, it is easy to see how enormous a quantity in all must be brought in every day—no less than eight or ten thousand tons. And inasmuch as air can not be moved, any more than any thing else, without a force to move it proportioned to the weight to be moved, it is easy to see how great an ascending force in the chimney must be required to bring this amount up through them, and how large a proportion of the coal that is burned must be required to produce heat enough to furnish it.

Intelligent and thinking people, in crossing the Atlantic in one of these steamers, are often much impressed with the fact that more than a hundred tons of coal are burned every day, as an indication of the vast scale on which the force-developing power of the engines act. But the thought that the ship, as she glides along on her way, has to gather from the circumambient air and draw into her fires *eight or ten thousand tons of air* to carry on the combustion of this coal, seems to be really more impressive still. She draws it in as air, and sends it out again, through her chimneys, a confused compound of carbonic acid, water, deoxydized nitrogen, and unconsumed hydrogen and carbon, leaving a long train of these mingled elements, or of such of them as are visible, in the air to mark her track.

There is another track which she leaves to mark (though not visibly) her way, and that is a line of slightly-warmed water in the sea. There is an enormous quantity of waste heat, in spite of all the precautions taken by the machine-makers and the engineers to save it, which escapes through the iron of the ship into the water that bathes her sides. Thus she leaves in her wake a line of warmed water—but slightly warmed, it is true, but still really warmed—which, if it were cognizable by the senses, would indicate her path.

Both these tracks, it is true, are very evanescent. The winds soon dissipate the one left in the air, though it remains visible sometimes, in the long line of smoke, much more persistently than we should expect, while the waves and currents soon obliterate the traces of the warmth left in the water. But, evanescent as this latter trace is, a very large fraction of the heat developed by the combustion of the coal in the furnaces is wasted in making it. In other words, the company expends a very considerable portion of its annual outlay in warming up the sea.

Besides these two very evanescent tracks made by the ocean steamers, there is another quite permanent one, though to us invisible, that they are making on the bed of the ocean by the deposit of the cinders and the ashes thrown overboard as refuse from the fires. All the steamers from America to England pursue substantially the same track. The space which these tracks cover is, it is true, pretty wide in mid-ocean, as the ships take more northerly or more southerly courses according to the season, or to the probability of encountering ice, or from other considerations. This deviation, however, is not very great; and inasmuch as steamers are continually passing over this space, each of which throws overboard many tons of this black refuse every day, and have been doing so now for more than a quarter of a century, the general course which they have taken must be marked on the bottom with a dark deposit like a broad black road. If this deposit should be mingled as it falls, and partially covered after it has fallen, with the general sediment of the sea, proceeding from the turbid flow of the rivers into it, and if, moreover, the process should go on as it is going on now for five hundred or a thousand years more, then strata of rock of very considerable thickness would be formed, tinged with black throughout the whole extent of them by the presence of this mass of ash and unconsumed carbon.

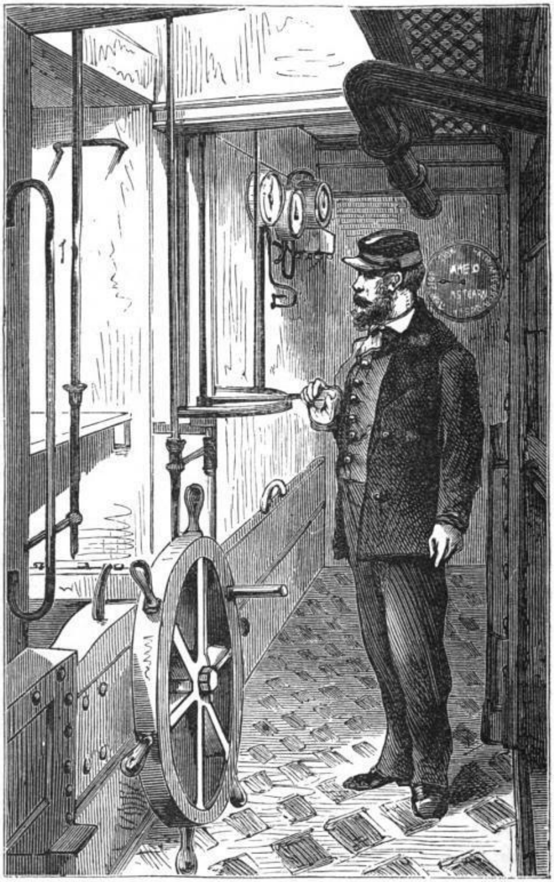
And then, if at some future age of the world this subaqueous formation should be upheaved by the action of these vast geological forces by which such upheavals have been effected in former times, and new continents should be thus formed, these strata would come into view, and might be quarried, and the blocks used in the construction of buildings, and the geologists of those days might wonder how such a rock could have been formed, and whence the carbon it contained could have been derived.

It is indeed true that the quantity of ashes and cinders thus thrown over, though absolutely very great, is in each ejection relatively very small compared with the immense extent of a roadway fifty or one hundred miles wide and three thousand miles long; but then, on the other hand, a thousand years is a long time, and there is no special reason for not supposing that the process may go on for even a longer period than that; and as at every discharge of these substances from the ship the operation occupies perhaps half an hour, during which time the ship has passed over a stretch of five or ten miles, the whole amount must be pretty evenly distributed.

The question, however, of the strata of rock thus formed, when finally upheaved, being tinged with black, would depend upon whether the carbon remained in the formation, as coal, unchanged, or whether, through the effect of chemical action, it was changed into some other form. The diamond consists of carbon in a crystallized form. Under what conditions the crystallization takes place is not known; nor do we know at all to what conditions such a deposit of carbonaceous material would be subjected at such a depth, and for so long a period. We at any rate know nothing to exclude the supposition that portions of it might become crystallized, and thus the refuse coal rejected from the ships employed to take fashionable ladies across the Atlantic at our age of the world, be employed, in the mysterious laboratory of nature, in forming the diamonds for the fashionable ladies of a distant future age. The transformation would not be, in fact, half as wonderful, nor, when considered beforehand, nearly as improbable as the formation of a strawberry out of juices drawn from the ground by means of chemical and physiological arrangements concealed in a slender stem six inches long.

But these are all mere speculations—idle speculations—some might say. But Lawrence, in discussing them with the boys, did not consider them as really idle, since the boys were much interested in the consideration of them, and such conversations accustomed them to the carrying of their thoughts beyond the region of the senses, to the contemplation of phenomena and powers in the great realm of nature which the senses can not bring to our cognizance.

Even Flippy was beginning to be considerably interested in the explanations which Lawrence gave him of the



AN ENGINEER AT HIS POST.

hidden workings of the various processes and changes connected with the combustion of carbon, and he had a desire, as children always have when they find out any thing new, to tell what he had learned to some one else. He attempted to explain to his mother something which he had learned, and which seemed to him very curious, about the working of the engine, but she did not take any interest in hearing what he had to say.

"Oh, I know all about it," she said. "I have been down myself—part way. Some people were going down, and they asked me to go with them. But I was satisfied very soon. It is an awful place. I did not go more than half way down. But then I went far enough to see the whole of the machinery, and I understand all about it—the cylinder, and the steam-pipe, and things. I have seen them all, and I know all about it."

Mrs. Gray did not seem to be aware that there is a great deal that the mind can know about any thing that is remarkable that lies entirely beyond what the eye can see.

CHAPTER XI.

WHAT IS SMOKE?

COMBUSTION, contrary to what young persons might in general suppose, is a very exact process. Oxygen can combine with carbon or hydrogen only in certain precise and definite proportions. In making the combination it will give out just so much heat. It can not be prevented from giving out the full amount, nor can it in any way be made to give out more. And that amount of heat can be made to afford just so much and no more power for driving an engine, or doing any other useful work.

If there is an excess of carbon in the furnace, none of the excess will be burned. The oxygen that is admitted will not combine *partially* with the whole amount, but will combine *perfectly* with a part of it—just the quantity that it requires—and will not touch the rest at all, but will leave it in the form of cinders in the fire, or allow it to be carried off in minute black flakes up the chimney as smoke. If there is more than the proper proportion of oxygen, *only the proper proportion* will be combined with carbon, and the rest will go up the chimney free and uncombined.

Thus the union of oxygen and carbon is governed by a law very different from that observed in the case of the solution of sugar or salt in water. In a glass of water you can put any quantity whatever of sugar or salt—as much or as little as you please, up to a certain amount—and it will all be dissolved, and will be diffused equally throughout the whole mass of the water, and in a certain way will be closely united with it. But this kind of union is not *chemical* union. Chemical union is considered to be a very much more intimate union than this, and always takes place in precise and definite proportions—just so much of one substance to just so much of another—any surplus of either substance being left entirely unchanged.

To our senses the union between the salt or the sugar and the water seems as intimate as possible, but the difference between such unions and that of chemical combination is very evident in the results, inasmuch as in the former case the *nature of the substances is not changed.* The sugar, for example, remains sugar, and the water remains water after they are united as before. You can taste them both. The particles, no doubt, lie side by side in the mixture unchanged, as poppy-seeds and grains of gunpowder of the same size would, if intimately mingled. The particles of sugar, or salt, and water are infinitely smaller than the seeds or grains, so that our senses, on the closest examination, can not discern them; but, when mingled in the solutions, they remain unchanged. In the case of *lye*, on the other hand, which consists of potash dissolved in water, and any oily substances mingled with it at a boiling heat, the result is that a soap is produced, which is not a mixture of oil and potash, but a substance entirely different from either, and having entirely different properties.

So, if you put a little whiting into a cup and pour water over it, you will have merely a *mixture* of whiting and water; neither will be changed. The whiting will remain whiting, and the water water, though never so intimately mingled. But if, instead of water, you pour vinegar upon the whiting, you will have a different result. Instead of having whiting and vinegar in the mixture, you will have new substances formed, entirely different in their nature and properties from either of those that you put in. One of these new substances will be a *gas*, which will pass off in bubbles into the air, and what remains in the cup will be something entirely new. There will not be a particle of whiting or of vinegar there, provided, of course, the two substances were mingled in the right proportion, so that the whole of each had the proper quantity of the other at hand to combine with it.

It is true that the *elements* of the substances brought together will remain in the products, but they will be formed into new combinations, so that the old substances will entirely disappear, and new ones, sometimes of an entirely opposite character, and of opposite properties, will take their place—that is, provided that the union is a *chemical* union.

Now combustion is a chemical union. The wood, or the coal, or the substance, whatever it is, that is burnt, disappears entirely as wood or coal, and the oxygen disappears as free oxygen. To speak in a more strictly scientific manner, however, I should say that the carbon and hydrogen generally contained in the wood or coal disappear as carbon and hydrogen; for there are other substances contained in the wood or coal with which the oxygen can not combine in the combustion, and these remain unchanged and form the ashes. The reason why these substances can not burn is because they have been burnt already. Or, to speak scientifically, the reason why they, too, as well as the carbon and hydrogen, can not combine with the oxygen, is because they are substances which are already combined with oxygen in the exact proportion of their capacity for it, being substances which were taken up from the ground by the roots of the plant. Thus, when the sun separates the carbon and the hydrogen from the oxygen in the leaves, to use them in forming the tissues of the plants, a portion of these earthy substances were employed with them, and remained, forming a part of the substance of the wood or the coal. Then, when the time of combustion came, the oxygen could only reunite with the carbon and hydrogen which had been separated from it, while these earthy substances, being already oxydized substances, remained unchanged.

Thus the union of carbon or of hydrogen with oxygen in combustion is a *chemical* union, and is marked by the two essential characteristics of such union, namely,

1. The combination is in definite proportions. A certain quantity of oxygen can combine with a certain precise quantity of carbon, no less and no more. And,

2. The result of the union is the production of new substances quite different in their nature and properties from the substances combined.

Lawrence, when he had finished explaining all these things to the boys, said to them,

"And now, boys, if either of you wish to remember all this, the way is to run it into your memory through the tips of your fingers. The very first time you are on deck and see volumes of black smoke coming out of the chimneys, say to yourself, 'Nearly all that is carbon, in very fine particles, which could not find oxygen enough to combine with it in the fire; for oxygen can only take up a certain amount, so much and no more, since substances can combine chemically only in precise and definite proportions.'

"When you see the smoke coming out in that way the first time," continued Lawrence, "you say that once, and touch one finger. When you see it the next time, you say it again upon another finger; and by the time that you have gone over the fingers of both hands, and perhaps even of one, you will have impressed the principle upon your mind so strongly that you never will forget it."

"But I could not remember all that," said Flippy; "I could not remember half of it."

"Oh, you need not say it in those words," replied Lawrence. "You can make up any words you please to express the idea."

"But I could not make up any words at all," said Flippy, "to say such a thing."

"Neither could I," said John.

"Try," said Lawrence.

So John, after looking up intently into the smoke a moment, said, speaking in a somewhat slow and hesitating manner, as if thinking what to say,

"Well, all that black smoke is made up of little particles of carbon that did not find any oxygen to seize it. Does the oxygen seize the carbon, or the carbon the oxygen?" said John, interrupting himself to ask the question.

"They seize each other," replied Lawrence; "or, at any rate, the force acts between them, and whether it resides any more in one than in the other we can not say. The truth is, we have no very clear idea of what force is, or in what it consists, when we attempt to form a conception of it, pure and simple. We pass there out of the realm of human knowledge—at least we pass out of the realm of *my* knowledge. I'll ask the major about it some day, but I don't think he can tell me any thing that is satisfactory. We give the name of force to something that produces motion. We have an idea of motion, but none of the force producing it, distinct from that of the motion. At any rate, I don't think we can make any distinction between two substances having a strong affinity for each other, in respect to the affinity being exercised more by one than the other."

"Well," said John, "then I will say they are particles of carbon that did not find any oxygen to combine with."

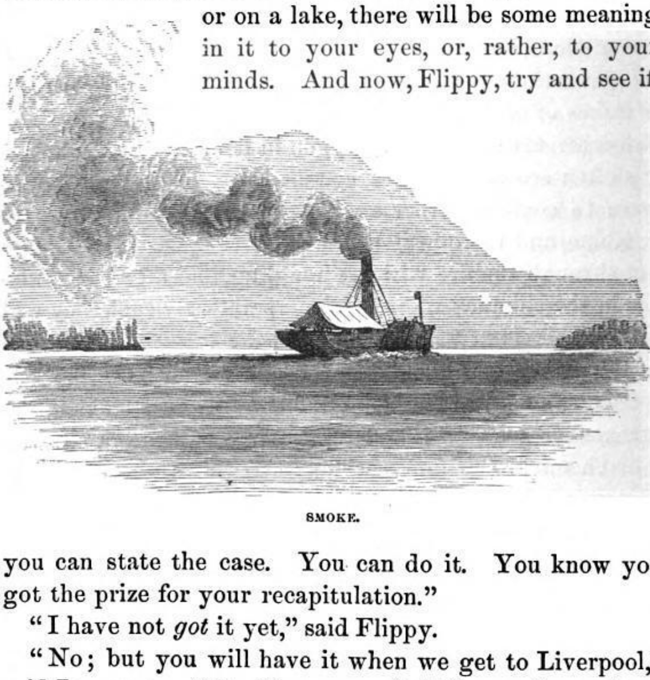
"Very good," said Lawrence.

"Because," continued John, encouraged by Lawrence's commendation, "there must be just so much oxygen for so much carbon, and if there is any excess of either it has to go up the chimney just as it is."

"That is all right," said Lawrence. "And then there is a large quantity of the other substances that pass through the furnaces, which escape up the chimney uncombined. For you see they must not only come together in the right proportions, but they must come together in *a hot enough place* for them to combine. There might be a little stream of flakes of carbon coming up through the fire in one place, and a stream of air with oxygen in it in another place, as we often see happen in a common fire. If these streams were to come together *in the fire*, the substances would combine, and more heat would be developed. But if they get through the fire without mingling, and afterward mingle in the chimney when it is comparatively cool, they will *not* combine, but will come out at the top of the chimney in the smoke, and float away into the air unchanged.

"The amount of it is," continued Lawrence, "that in the furnace of a steam-engine, or in any other fire, there are four chemical substances concerned, only three of which, however, take any active part. These three are carbon, hydrogen, and oxygen. The fourth, which takes no active part, but only does mischief by being in the way and preventing the others from acting, is nitrogen. Of the three, the carbon and oxygen, so far as they come together in the right proportions, and in hot enough places, combine, and form carbonic acid. The same with the oxygen and hydrogen, only they form vapor of water. All the carbon and hydrogen which do not find any oxygen to combine with them in the actual fire, and all the oxygen that does not find any carbon and hydrogen, go up the chimney together, and form the smoke. But all that part of the smoke that we can see is formed of minute particles of the carbon mixed with the vapor of water, for all the other substances are transparent gases, entirely invisible.

"It is a great deal better to understand all this," added Lawrence, "for then, when you see a thick smoke coming up from a chimney, or from a fire in the woods, or from a burning building, or from a steamer's smoke-pipe on a river or on a lake, there will be some meaning in it to your eyes, or, rather, to your minds. And now, Flippy, try and see if



SMOKE.

you can state the case. You can do it. You know you got the prize for your recapitulation."

"I have not *got* it yet," said Flippy.

"No; but you will have it when we get to Liverpool," said Lawrence. "Or, if you are afraid I may forget it, or may not have an opportunity to give it to you, I'll give you the money now—enough to buy a compass for yourself—if you prefer."

"How much should you give me?" asked Flippy.

Lawrence hesitated a moment, and then said, "A shilling."

"An English shilling or an American shilling?" asked Flippy.

"An English shilling," replied Lawrence.

Flippy hesitated for a moment, and then said he would prefer to wait and let Lawrence buy the compass himself. He thought that if he waited and allowed Lawrence to buy the compass, he would very probably get one that would cost more than a shilling. Flippy did not evince much delicacy of mind in looking out so shrewdly for the value of the prize which he was to receive, when the prize was earned, if a prize in such a case can be said to be earned at all by his merely having attended well to certain instruction which was of great benefit to him to receive, but of no benefit at all to Lawrence to impart. But delicacy of mind is a quality that is developed late and slowly compared with many other faculties, in all children, and especially in such boys as Flippy. Flippy had a great many excellent qualities, but he had not yet acquired this. Any one would have evinced great ignorance of human nature, and of the order in which the different moral sentiments are developed in the minds of children, to have expected it of him. Lawrence did not expect it, nor was he at all surprised or disappointed in not finding it in him. In a word, he knew something of the philosophy of mind as well as of the philosophy of matter.

CHAPTER XII.

THE "FIDDLE."

THERE is an important truth in the sentiment that Lawrence expressed to the boys in saying that the knowledge of the philosophy of any phenomenon or process which takes place in the world around us imparts a great significance to the appearances which they present to our view, and so greatly increases the interest which we take in them. The boys had an illustration of this the next time they went by the "fiddle," for it was by this whimsical name that the apparatus for hoisting up the ashes and cinders, or the place where this operation was performed, was called. Seamen and printers, though so entirely unlike in many respects, are very much alike in the oddity and grotesqueness of the names they fancy for any thing that they have to name.

When John and Flippy had passed by the fiddle before, and had witnessed the hoisting up of the ashes and cinders, they had been interested in it only as a mechanical operation. They listened to the rattling of the machinery, and to the change in the sound as the full tubs were brought up or the empty ones sent down. They watched the long chain as it came up from the deep well, thus measuring the depth, which seemed wonderfully great, and were impressed with the strength and vigor exhibited by the men in carrying off the heavy tubs or buckets so rapidly to the ship's side, and emptying the black and smoking contents through the shoot into the sea.

Now, however, after Lawrence had explained to them the nature and character of the cinders, and of the ashes mixed with them, there was a much greater significance in the operation than when they saw it before. Their thoughts descended into the furnace where they had seen the firemen throw in the coal on the day when they went down among the machinery, and they pictured to their minds the furious heat developed by the force with which the carbon united with the oxygen that came within its reach. They saw how, in the immense rush and turmoil of the air in passing through the fire, many small fragments would escape combustion, and would get covered by the ashes left from the portions that were burnt, and then, with the ashes, would fall down through the bars of the grate to the ash-pit, where the heat was not great enough for any stray oxygen which might be there to combine with them. From the ash-pit they saw the cinders brought up hot and smoking, but not hot enough for combustion to go on, in the great iron buckets to the deck, and then cast into the sea. They followed them in imagination there as they were spread along the water by the swift advancing motion of the ship, and sank gradually down, the heaviest portions going in advance, and the lighter ones following more slowly. They pictured in their minds, too, the long dark track which they must leave on the bottom of the sea, and reflected how this track must be gradually widened, and extended, and made continuous by the repeated voyages of the same and other ships, until, in the course of centuries, the whole bottom of the sea in the line of their course would become blackened with them.

While John was considering these things, Flippy suddenly said,

"If we had such a place as this on land, what a grand thing it would be to play going down into a mine."

"Yes," said John, "it is very deep. See how far down the chain goes! They let you down into real coal mines in very much such a way as that. You get into a monstrous great bucket or tub, and they let you down by a windlass and chain."

"*These* buckets are big enough for me," said Flippy. "I mean to ask the men to let me down. It will be good fun. I'll play that I'm going down into a mine."

"No," said John, seizing Flippy at the same time by the arm in order to restrain him, "you will get your clothes all covered with ashes and cinders."

"That's nothing," said Flippy; "I can brush them clean in a minute when I get down. Besides, these clothes are only old ones which I brought to wear at sea."

"No," said John, "you must not go."

"I'll stand up straight exactly in the middle of the tub, and not touch the sides at all," said Flippy.

"No," said John again, "you *must not* do it. Besides, the men would not let you do it."

"Let me just ask them," said Flippy.

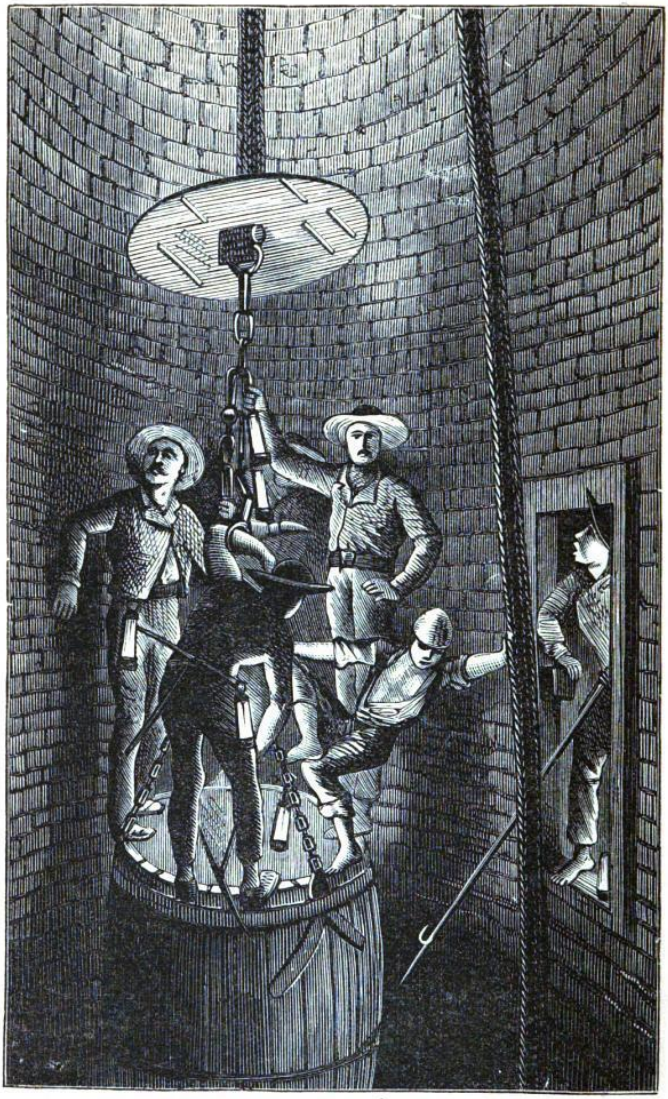
As he had been pulling all this time to free himself from John, and seemed to insist so strenuously upon his determination, absurd and preposterous as it was, John now partially released his hold, being confident, moreover, that if Flippy were to ask the men he would be at once refused. Flippy accosted one of the men at the chain with,

"I say, let me down into the hold in one of those empty buckets."

The man looked at him a moment with an expression of mingled surprise and amusement in his countenance, and then said,

"All right! when the next bucket comes up, jump in."

But John immediately took hold of Flippy's arm again and pulled him away, saying that he positively must not do any such a thing. It would be the worst kind of a mis-



GOING DOWN BY A TUB.

demeanor, he said. He would have to pay at least a double fine for it.

So Flippy allowed himself to be drawn reluctantly away.

"I think even your asking to go was a peccadillo," said John, "and that you ought to pay a two-cent fine, at any rate."

"No," said Flippy.

"I'll leave it to Lawrence," said John.

"I'd just as lief leave it to him as not," said Flippy.

So the boys went together to find Lawrence, and stated the case to him.

"He wanted the men," said John, "to let him go down into the hold in one of the empty buckets, all black with ashes and cinders, and I had the hardest work to prevent him."

"I wanted to see how astonished the stokers would look," said Flippy, "to see such a boy as me coming down among them in that way."

Lawrence paused a moment, and then said it seemed to him that was rather a foolish thing to do.

"Not a bit more foolish than it is for people to be let down into a real mine by a big tub, and ropes, and chains, in almost exactly the same way," said Flippy.

Lawrence, who had himself gone through with that experience, rubbed his mustache to conceal a smile, and admitted he did not know exactly what to say in reply to that argument. Still he must consider, he said, that attempting to do such a thing on board ship, and putting John to the trouble of preventing him, was a peccadillo, and that he must be fined two cents.

"All right!" said Flippy; and he at once put his hand into his pocket, and, drawing out some money, paid his fine in the most good-natured manner possible.

"And this reminds me," said Lawrence, "of the question between you and me, John, about the comparative combustibility of wood and iron. We have never settled that question. We were to leave it to the major."

It was agreed, after a little farther conversation on the subject, that they would ask the major to hear and decide the question that evening after tea. They told Flippy that, if he wished, he could come too. He said he thought it was very foolish, but he would like well enough to hear what they had to say about it.

Accordingly, that evening, after tea, the boys took the major to a part of the table where no one was sitting, and proposed the question to him. But, in order that what he said upon the subject in giving his decision may be understood by the reader, I must make one explanation, which is this: that all substances do not *ignite*, as it is called—that is, *take fire*—at the same temperature. In other words, the degree of heat at which oxygen will begin to combine with another substance, with that intensity of action and that development of light and heat which constitutes combustion, is quite different in different substances.

For instance, if we should place a bit of phosphorus, one of sulphur, and one of coal, all of the same size, upon a shovel, over a hot bed of coals, and if the iron of the shovel were of equal thickness in every part, and the heat of the coals the same in every part, so that the three combustibles should all be gradually heated in the same degree, they would begin to burn at very different times, showing that they require different degrees of heat to commence the process of combustion.

The phosphorus would begin to burn first, then the sulphur, and last of all the carbon.

We take advantage of the different degrees of heat thus required in the construction of phosphoric matches. Phosphorus requires so slight a degree of heat to ignite it that a gentle rubbing is sufficient. When we rub the match—which we do upon something that is a little rough, in order to increase the friction—the phosphorus that happens to be on that part of the match which comes in contact with the rubbing surface is heated, so that it begins to burn; that is, it is heated so as to bring it within the power of the oxygen floating in the air all around it to seize and combine with it. The oxygen, in combining with it, develops more heat, and this prepares the next particles of phosphorus to be devoured, and the heat which they develop the next, the intensity of the heat increasing all the time as the burning advances. This heat soon brings the sulphur that is close at hand up to the *point of combustion for sulphur*, and this second combustion develops more heat still. But some little time elapses before the heat becomes sufficient to raise the carbon of the wood up to its burning point, which is a good deal higher than that of sulphur. You will see the little faint blue flame of the sulphur floating about the end of the match for quite a little time before the heat accumulates sufficiently to bring the temperature of the wood up to the burning point of the carbon and hydrogen of which the wood is composed.

Now the fact in respect to iron is, that it has a strong affinity for oxygen, and will combine with it, either in a slow and gradual manner, at the common temperature of the atmosphere, or in a very violent and rapid manner by the process of combustion; but it requires either so intense a heat when the supply of oxygen is limited, or such an abundant supply of oxygen when the initial heat is not very great, that in all the ordinary exposures to heat and oxygen which iron undergoes in the practical purposes of life, it is perfectly safe from taking fire at all. It burns only very partially even in the great heat of a blacksmith's forge.

CHAPTER XIII.

BURNING OF IRON.

As soon as the party which was collected to hear the major's decision of the question in respect to the comparative combustibility of iron and wood were seated in the saloon—the major on the back side of the table, under one of the windows, and Lawrence and the boys on the front side, facing him—the major opened the business by asking,

"Well, young gentlemen, what is the question now?"

"The question is," said John, "which is most combustible, wood or iron."

Now the major was very quick and prompt in all his actions, as military men are apt to be, but he was also very exact and precise. Indeed, the habit of exactness and precision, and a very distinct and clear apprehension of the points to be considered are quite necessary as a means of making promptness and rapidity of action safe.

"Ah!" said the major, "that's rather a nice question." Then, after musing a moment, he repeated the words, "Which is *most* combustible?"

"Yes," replied John; "Lawrence says that iron is the most combustible, and I say that wood is."

"It depends upon exactly what you mean by combustible," said the major. "Were you talking science, or was it common conversation?"

"It was common conversation," replied John; "I said I was glad we were coming in an iron ship, for an iron ship could not burn. But Lawrence said that iron was more combustible than wood."

"More strictly and completely," said Lawrence.

"Did he say strictly and completely?"

"Yes, I believe he did say something like that," replied John.

"That makes it difficult to decide the question," said the major. "If he had simply said in common conversation, and talking about ships at sea, that iron was more combustible than wood, so as to give the idea that an iron ship would be more easily burned than a wooden one, he would have been wrong; for, in common parlance, iron is not combustible at all—that is, it will not ignite under any ordinary circumstances in respect to temperature and supply of oxygen. But by saying *strictly* and *completely*, he qualified the word combustible, and gave it in some degree a scientific sense. And in that sense he was right; for iron will combine with oxygen in combustion if the temperature and the supply of oxygen is right. And it combines *completely*, for every particle of it will be consumed. If there is any thing in the mass that is not consumed, it must be some other substance accidentally present, and forms no part, really, of the iron.

"But with wood it is different. There are certain earthy substances in wood which help to form the wood. They are thus parts of the wood. But they will not burn, for they are already oxydized. Thus wood, as wood, is not wholly combustible, but iron, as iron, is.

"So, in a scientific point of view, Lawrence was right; but in respect to the use of language in common parlance, he was wrong. And as I may consider that there was some little doubt in which light the words ought to be regarded in such a conversation as that, I shall give the benefit of the doubt to the youngest party, and decide the question in favor of John."

The major was always very ingenious in finding grounds for deciding all questions in favor of the weaker party. He took great care, however, in doing this, not to disguise or confuse in any way the truth in respect to any principles that were involved in the question.

John was, of course, well satisfied with the major's decision, but Flippy shook his head and looked incredulous, and said that he never thought that iron was combustible at all, and he could hardly believe it now. The major said he could prove it to him if he had a file and a piece of wire, or any other piece of iron that he could file so as to let the filings fall into a flame.

"The reason," said he, "why any ordinary piece of iron will not burn in a common fire is because it is too large in proportion to the heat of the fire and the supply of oxygen. If we make the particles small enough, iron will burn splendidly in the flame of a candle. If I had a file here I could show you in a moment."

So saying, the major looked about him, and felt in his pockets as if he expected to find such a thing as a file in an elegant gentleman's pocket, or on the tables of a gay and splendid saloon of an Atlantic steamer, filled with groups of ladies and gentlemen, after tea, on a pleasant summer evening.

He drew from his pocket, not a file, but a handsome knife of several blades.

"Perhaps this will do," he said. He took from another pocket a key, and then drew one of the candles which was on the table near him, and, calling the boys to look, he began scraping the key with the back of the large blade of the knife, holding it, while he did so, over the flame.

The portions of iron which were thus separated from the key by the corner edge of the back side of the blade were, of course, exceedingly minute—so minute that they were entirely invisible until they fell into the flame, where, in burning, they flashed into beautiful scintillations, very delicate and fine, it is true, but very beautiful.

"They burn just like gunpowder," said Flippy.

"They burn as really and truly as gunpowder," said the major, "but not like it. The burning of gunpowder is the combustion of sulphur and carbon."

"And saltpetre," said John.

"No," replied the major. "The saltpetre does not burn; it furnishes the oxygen for the burning of the other two ingredients. That's the secret of the force of gunpowder. The sulphur and the carbon, two combustibles, are mixed intimately with a substance which furnishes oxygen close at hand, and so they burn with great rapidity. But the flame of sulphur and carbon is very different from that of iron, as we should see if we had some gunpowder to try."

Flippy said that they must have gunpowder on board, for they always fired a gun on leaving and entering port, and he would go and ask one of the waiters to get him some. He was about starting off for this purpose, but the major stopped him, saying that, although such pyrotechnics as had been produced by iron scrapings from a key into the flame of a candle might be allowable, an attempt to play off fireworks with gunpowder in such a saloon, in the middle of the Atlantic, might be thought rather out of place. So he must take it for granted that gunpowder would burn, and fancy the kind of flashes that it would produce, without the experiment.

The major then scraped some particles again from his key into the flame, to let the boys witness it once more.

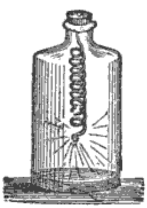
While he was doing this, a young lady, who was one of the passengers, came by, and stopped to see what was going on. Lawrence seemed to be acquainted with her. He made room for her to see, and explained to her that the major was showing the boys that iron would burn.

She looked at the scintillations for a moment with a languid interest, and then said she never knew before that iron would burn.

"And I don't believe that it really burns now," she said. "It only sparkles. It can't really burn. Yes, I remember once I was at a lecture, and they made some iron burn in a jar, but I thought that was only an experiment." So saying, she walked away.

Her idea of an "experiment" was, it seems, that of something contrived artificially to amuse people at a lecture, but which had no counterpart in nature. An experiment thus had no meaning to her as the revelation of a general law. It was a crackle or a flash, or something else odd and singular, special to the occasion. It brought to her mind no conception whatever of any great principle or law of universal or permanent force in the external world, such as it does really, in fact, always indicate to those who regard it aright.

In the experiment to which Miss Otis referred, and which is very often performed in the lecture-room, a slender piece of iron or steel—a portion of a watch-spring, for example—with something to kindle it at the extremity, is let down into a jar previously filled with oxygen.



COMBUSTION OF IRON.

The effect is very striking, and it always interests those who witness it very much. But they ought to consider it as the manifestation of a universal law of nature in respect to the nature of iron and its relation to oxygen, and not merely as a sparkling light, to surprise or to amuse for a moment by its brightness those who observe it.

Lawrence repeated several times the experiment of burning the iron shavings or raspings in the candle while John and Flippy looked on.

"It is very pretty," said Flippy, "but I don't think it is very *splendid*, as you said."

"Splendid, I meant, in proportion to the size of the articles burned," replied the major. "They are as small as the finest dust. I suppose they are so small as to be entirely invisible."

So saying, the major took out a letter from his pocket and scraped his key over a portion of the white paper, just as he had done over the candle. The boys, on examining the paper, could see nothing at all.

"Now if particles of iron so minute as to be invisible make such a sparkling as we see," said the major, "think what an inconceivably splendid conflagration would be produced by the burning of a beam of iron two feet through, like some of the beams in our engines!"

"But it would be impossible to burn such a big beam as that," said Flippy.

"The only impossibility would be," replied the major, "that of obtaining a high enough heat and an ample enough supply of oxygen in proportion to the size of the bars of iron. I am not certain, indeed, that it might not be done, if there were any sufficient inducement for attempting it."

In concluding this chapter, I will say that any person who chooses can easily repeat the major's experiment of showing the combustibility of iron by scraping fine particles from a key, or the back of a kitchen-knife, or from an old pair of scissors, or any other piece of iron or steel, into a gas or lamp flame. Indeed, these particles are so fine that, if the scraping is done *beneath* any naked flame that is sufficiently powerful—as, for example, that from an open gas-burner—they will be drawn up into it by the ascending current of air, and the effect will be all the more striking.

CHAPTER XIV.

FLAME.

It was stated in the last chapter that there was a great difference in the degrees of heat which different substances require for the commencement of that process of rapid combination with oxygen, attended with the development of great heat and light, which we call *burning*, or *combustion*. This principle, in relation to carbon and hydrogen, the chief components of wood and coal, explains some very curious effects which are to be observed in a common fire made of those substances.

A burning coal is an incandescent *solid;* a flame is an incandescent *gas*. Now hydrogen, in its ordinary state, is a gas, and of course, when it is burning, it forms flame. Carbon, on the other hand, in its ordinary condition, is a solid, and thus, when it is incandescent—that is, when it is at such a high temperature as to emit a bright light—it forms a burning coal only; that is, an incandescent solid, and not a flame.

While a candle is burning, the substance of the flame is of hydrogen, though it is filled with incandescent particles of carbon in an extremely comminuted state. When we blow out the candle, the combustion of the hydrogen ceases; but if the wick is still alive, the fire in it consists of the combustion of the carbon in the wick, which combustion still goes on for a time after that of the hydrogen is arrested.

The philosophy of blowing out the candle is simply that the breath cools the incandescent hydrogen below the point at which the combustion can go on, and blows it away. It does not extinguish the wick as readily as it does the flame partly because the incandescent carbon is solid and can not be blown away, and partly because the combustion of carbon can go on at a lower temperature than that of hydrogen.

The difference between these two substances in respect to the temperature at which combustion takes place, and to the appearance which they respectively present when in a state of incandescence, is shown still more strikingly in the case of a fire in a fireplace or grate, or in the open air. In all these cases the hydrogen and carbon burn separately, and give rise to very different phenomena.

In the first place, the hydrogen, if it is desired, can be entirely separated from the carbon, and burned by itself. This may be done by means of an experiment which may easily be performed. Take a common tobacco-pipe with a long stem; fill the bowl nearly full of any dry fuel, such as sawdust, or shavings of wood, birch bark, or bituminous coal; close the top of the bowl with wet clay; when the clay is dry, put the bowl of the pipe in among the coals of a hot fire, placing it so that the stem shall project upward and outward; the stem can be easily supported in that position by allowing it to rest upon the andirons. In a few minutes smoke will appear issuing from the end of the pipe-stem. This smoke will consist chiefly of hydrogen, though there will be mingled with it a portion of carbon in a state of very minute division, which has become separated from the fuel and borne away by the current of hydrogen. This gaseous stream issuing from the pipe can be set on fire by touching a match to it, and it will continue to burn until all the hydrogen which was contained in the fuel has been expelled.

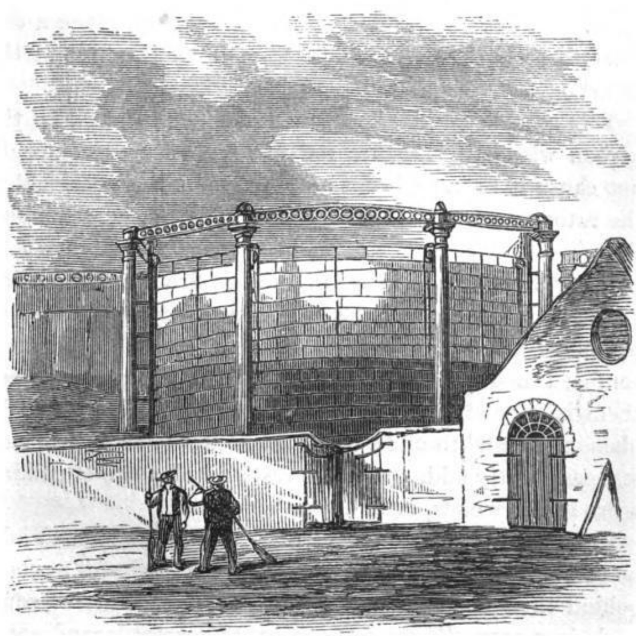
After the hydrogen has thus been exhausted, if you break out the clay stopper and examine the residue left in the interior of the pipe, you will find the principal portion of the carbon remaining in it, black but unburned. It was heated *hot enough* to burn, but it could not burn, for burning is combining with oxygen, and there was no supply of oxygen for it in the bowl. The hydrogen itself could only burn when it issued from the end of the pipe, where it came in contact with the air.

This is the way, substantially, that gas is produced for the lighting of cities and towns. Some hydrocarbon—often a kind of bituminous coal—is placed in large clay or iron vessels, called retorts, which are set in brick furnaces, where hot fires are built under them. The hydrogen is thus separated from the carbon, carrying with it, however,

FILLING A RETORT.

a considerable quantity of the latter in a state of very minute division, and is stored in immense gasometers, whence it is conveyed in pipes underground wherever it is required.

When the idea was first proposed of lighting towns by gas of this kind collected and stored in immense reservoirs for the purpose, many people thought that such large accumulations of so combustible a substance would be excessively dangerous—as dangerous, so they thought, as so much gunpowder. It was not understood then as well as it is now that combustion can only take place in such cases by the action of oxygen, and that, if an opening were made into a gasometer, and fire applied, the gas could only



GAS-HOLDER.

burn as fast as it came out to where the oxygen could come in contact with it. It is said that one of the inventors of this method of lighting, on a certain occasion, in order to prove the safety of it, tried the experiment of lighting a stream of the gas coming from an orifice, much to the alarm of the spectators.

The case of gas is different from that of gunpowder, which has its store of oxygen in its own composition, and so does not depend at all upon that in the surrounding air.

The mass of carbon that remains in the gas retorts after the hydrogen has been all evolved from it is afterward taken out, and forms what is called *coke.* This may be burned afterward for the purpose of producing heat, though it will give out very little flame in being thus burned, inasmuch as all the hydrogen, which alone can produce a distinct flame, has been expelled from it by the heat of the furnaces.

This heat, however, though it was sufficient to keep the carbon within the retorts red-hot for a long time, could not cause it to burn, because there was no oxygen within the retorts to combine with it, and thus produce combustion.

Now, though in the case of an open fire the combustion of the hydrogen and of the carbon are not separated thus completely, but mingle or alternate with each other in a confused and irregular manner, the difference between them is very obvious to those who attentively watch the phenomena, and to understand the action of these two substances greatly adds to the interest and pleasure of making a fire in the woods, or in any other place.

For example, a boy named Eugene, and his sister Viola, went out one day to an open field in the border of a wood, behind their house, to build a fire. Eugene carried some coals in a pan. These coals were, of course, incandescent carbon. They were slowly burning from the outside inward as the oxygen of the air came in contact with the successive portions of them. The oxygen, of course, only combined with the particles of carbon, leaving the earthy matter which the wood from which the coals had been produced contained, in the form of a thin white film around the coals. From time to time Eugene stopped to blow this film of ashes away, and this made the coals brighten up by admitting the air more freely to the particles of carbon below.

Eugene and Viola stopped once or twice to watch these little films form on the surface of the coals. But they did not know any thing about the nature of them, nor what the reason was that it made the coals brighten up to blow them away.

Presently they came to the place where they were going to build their fire. Eugene laid his fire-pan, with the coals in it, down upon the grass, and began to gather wood for his fire. Viola helped him to find and bring the wood. They laid down two of their sticks upon the ground for andirons.

"Our fire will burn better if we have andirons," said Eugene.

This was true; for, by raising the wood which was intended to be burned above the ground, the air could bring its oxygen to it more easily.

Then Eugene laid some sticks across his andirons, placing two of them pretty near together, but leaving a little opening between.

"Now," said he, "we must put on the coals."

So he poured the coals over the interstice, or opening, between the two sticks of wood. The coals had, however, been lying in the pan so long, where but little oxygen could gain access to them, that the combustion had gone on very slowly. But when they were placed in this new position, the air around them was heated and swelled, and so became lighter and rose, while a fresh supply, bringing more oxygen, came up through the interstice; and this oxygen, combining at once with the carbon of the coals, began to give out more heat and light by the intensity of the action—that is to say, in other words, the coals began to brighten up immediately.

But the wood which lay next the coals could not take fire until it was heated up, by the contact of the coals, to the point of combustion. This, of course, required some little time. Very soon, however, the outer layers became hot enough for the combustion of the carbon, but not enough for that of the hydrogen. The hydrogen was, however, set free and began to rise, carrying up with it a great quantity of fine particles of carbon, forming a little cloud, which went curling upward into the air.

"See, Viola," said Eugene, "it is beginning to smoke. We want some kindling stuff to make it blaze. Go and see if you can find some kindling stuff."

So Viola began to look around for small slender sticks, and dried leaves, and other such light fuel. She and Eugene knew, both from their having been so told, and also from their own experience on former occasions, that a little heap of such things would take fire more easily and burn faster than solid logs of wood, but they did not know at all that the reason why they would do so was because the openings and interstices between them allowed each portion of the whole mass to be surrounded by air, so that every part had a supply of oxygen close at hand, while in a solid piece of wood the whole interior of the mass is wholly cut off from the access of oxygen, and can only be reached by it gradually, as the outer parts are burned away.

Viola soon brought a supply of kindling stuff, and Eugene put it on the fire. The fire worked up slowly through it, burning the carbon—for the heat was great enough for the combustion of carbon—but only setting the hydrogen free without burning it, for the heat was not sufficient yet, in any part, to allow the rapid combination of hydrogen and oxygen to commence; in other words, for the hydrogen to take fire. The hydrogen was set free, however, in great quantities, and came up through the kindling, mingled with the other gases, and with great quantities of finely divided carbon. In other words, the fire sent up dense volumes of smoke, but did not blaze.

"Viola," said Eugene, "if we only had a match, or piece of lighted paper to touch to our fire, we could set it a-blazing in an instant."

Eugene spoke very correctly in saying this. He would have been equally correct and more scientific if he had said,

"The carbon is burning finely, Viola, and the hydrogen is coming up very fast; but it has not got hot enough yet any where for the hydrogen to take fire. If we only had a match or a lamp-lighter with the hydrogen burning, and could touch it to our fire, it would light up the hydrogen in that in an instant."

It may seem strange that the heat from the small flame of a match or a lamp-lighter should be so much more effective than all the heat of the red-hot and burning carbon in a fire which smokes but does not blaze. But the truth is, that though the heat of the coals may be much greater in *amount*, it is not so *intense*, in any one point, as the heat of the smallest flame. It is in no part hot enough to bring the hydrogen up to the *point of combustion for hydrogen*, while the little flame *is* hot enough, though the heat is circumscribed within a very small space.

Nor is it at all necessary that it should be extended; for if the right *intensity* of *heat* is attained at any one point, the hydrogen will at once begin to combine with the oxygen at that point, and, in so doing, will develop heat much faster than while the carbon only was burning, and will spread the combustion almost instantly through the fire, wherever there are streams of hydrogen issuing from the fuel.

"I'm sorry we have not any matches," said Viola. "But can't you make it burn by blowing it?"

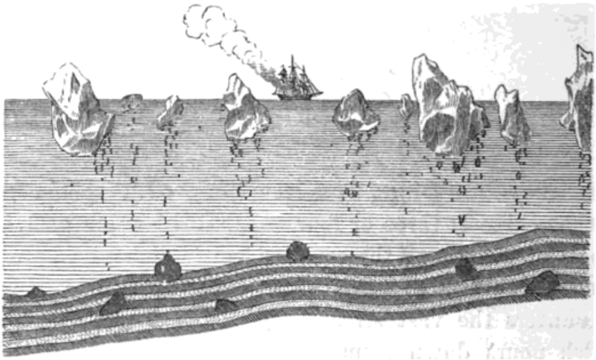
"I'll try," said Eugene; and, so saying, he kneeled down before the fire and began to blow with his breath under the fore-stick. In this way he sent a current of air among the coals which supplied them with oxygen faster than before. The oxygen then combined faster with the carbon, and this developed more heat, until in a few minutes the heat was raised in some one point high enough to *reach the point of combustion of hydrogen*, when all the hydrogen at once took fire, or, in other words, the fire burst into a blaze.

CHAPTER XV.

THE BANKS OF NEWFOUNDLAND.

A STEAM-SHIP sailing from New York to Liverpool comes, in the course of three or four days after leaving port, into a part of the sea, off the coast of Newfoundland, where the immense current of warm water from the Gulf of Mexico encounters the vast stream of floating ice and icebergs which pours down from Baffin's Bay to meet it. The causes which produce the vast and ceaseless flow of these two currents are very curious, but I can not stop to explain them here. The magnitude of them is enormous, surpassing entirely, as they do, the power of the human imagination to grasp them. The Gulf Stream is often compared to a river flowing through the ocean. It is a river some thousands of miles long, fifty miles wide, and a thousand feet deep, and flows incessantly at the rate of four or five miles an hour, making a stream about as large as *several thousand* Mississippi rivers all in one! It is an example of the conveyance of heat by the transportation of the heated substance and conduction, or *convection*, the grandest, probably, both in respect to the magnitude of the action itself and of the effects produced by it, that is known to man.

The encounter between this stream of warm water from the south and the current of cold water, bringing at certain seasons of the year vast mountains and fields of ice, produces some very curious effects. The rocks, and gravel, and sand brought by the ice are dropped, when the ice melts, in the region where the warm water meets the arctic stream.



ICEBERGS DEPOSITING ROCKS AND GRAVEL.

These deposits, which have been going on for many thousands of years—and no one knows how much longer—taken in connection with other causes, have produced vast shoals, called the *Banks*, which are the resort of immense quantities of fish, of the kinds that find their food best in shallow water. The gathering of the fish here brings fleets of fishermen. The encounter, too, of the warm and moist air which arises from the water of the Gulf Stream, with the chill produced by the icebergs and ice-fields, and the cold current of water, fills the air with fogs and mists, and produces gusts of wind and scudding clouds, which chase each other incessantly over the surface of the water.

Thus the confluence of the torrid and frigid currents at this point leads directly and indirectly to a heterogeneous assemblage of fogs, mists, squalls, shoals, icebergs, fish, and fishermen, such that it requires great tact and skill on the part of the organized intelligence of a sea-going steamer to carry the ship safely through it.

The difficulty is greater from the fact that there is found to be no serious advantage gained by any slacking of the speed. So the vast construction, with its town of a thousand inhabitants, more or less, on board, drives steadily on, at a speed three times as fast as a horse trots on a journey, through fogs, mists, and squalls, and among fishing-boats, ships, and returning steamers, trusting to the vigilance and alertness of that many-eyed and many-handed organization formed by the ship's company. They feel for the vicinity of ice by a thermometer let down into the water. They find their way by catching with the sextant occasional glimpses of the sun, his form half revealed at intervals through the driving mists and rain. They warn the invisible fishing-boats of their approach by blowing the steam-whistle, expecting them to answer with muskets or horns. One would not suppose that such precautions as these would be at all sufficient to make the passage through such a way even tolerably safe. But the sea is wide, and the obstructions, though numerous in the aggregate, are, in fact, in view of the vastness of the expanse, relatively rare, and the ships of the Cunard line have been traversing it incessantly for a quarter of a century without any serious harm.

It is not at all surprising, however, that some of the passengers, and especially ladies, feel a little nervous sometimes while traversing this part of the sea, especially if they rightly understand the state of things around them.

One day, while the steamer was on the Banks, at about a quarter past eleven o'clock by the steamer's time, which was really the time of her position at noon the day before, so that it was actually, where she then was, nearly twelve, the boys were on deck. The water was smooth, and the air was really calm, though quite a breeze was produced along the decks by the swift motion of the vessel. It was not raining, but a thin fog covered the water in every part, and veiled the sky, though the form of the sun could be seen sometimes faintly showing itself through it. Two or three of the officers were on the deck, with their sextants in their hands, trying to obtain an observation.

Another officer had just been superintending the operation of heaving the log, and twenty or thirty men were at work drawing in the log-line, which, though it is only a stout cord to be drawn through the water, comes in very hard. John and Flippy had been watching this operation, and when it was completed they went to a place where Lawrence was seated, near one of the smoke-pipes. As these smoke-pipes are ten or twelve feet in diameter, they afford a very good shelter from the wind; and as they become very hot by the vast quantity of intensely-heated gases that are coming up through them, they form excellent stoves of prodigious magnitude, around which the passengers find it very comfortable to gather on cold and chilly days. Lawrence was seated in a folding chair. The boys took seats upon camp-stools by the side of him.

"Now, Flippy," said Lawrence, "it is your turn to see whether you can repeat the substance of what I told you about the smoke coming out of the chimney."

Flippy looked up, and saw an immense volume of smoke emerging from the chimney and passing off toward the stern until it was lost in the fog.

"Well," said Flippy, "I'll try. All that smoke—that is, all the black part of it—is made up of fine particles of carbon from the coal that could not find any oxygen to burn it in the fire."

"Good!" said Lawrence; "that is just it. Quite a large portion of every ton of coal that they put into the furnaces comes out in this way without being burnt. Heat alone won't make it burn without oxygen. If it comes up through the hottest part of the fire at a place where there is not oxygen for it, it will not be burned, but will come up through the chimney in smoke. So they not only lose a great deal of coal by having it pass through the furnaces without giving out any heat, but the smoke which it makes on land sometimes does a great deal of mischief. I can't tell you how much time and money has been spent in England and in other manufacturing countries in trying to contrive means to prevent this carbon from getting through the fire without being burned."

"There is a great region in England," continued Lawrence, "where there are so many coal mines, and iron mines, and founderies, and machine-shops, all requiring immense furnaces and chimneys, that the whole country is filled with the smoke. They call it the Black Country."

"I should like to see it," said Flippy.

"It is very likely that you will go through it," said Lawrence. "It is very interesting to visit the works and witness the immense operations that are performed in them, but the smoke is a terrible nuisance. It injures the air for breathing, kills vegetation, and blackens every thing. And it is all the more vexatious because it is only the waste of a good thing that occasions it. If the carbon would only stay in the fire and be burned, it would do good by giving out more heat."

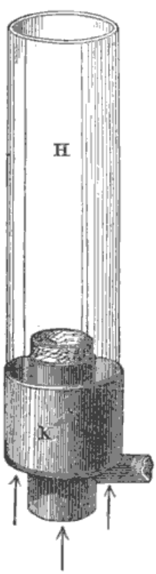
"I don't believe but that I could find out some way," said Flippy.

"Perhaps you may do it when you are a man," said Lawrence, "if you make as much progress until that time in looking into these things as you have done so far during this voyage. A great many men have tried, and some smoke-consuming furnaces, as they are called, have been invented, and, to a certain extent, they are successful; but they do not effectually remedy the evil, except in the case of lamps. A common lamp will smoke if it is turned up too high—that is, if the wick furnishes carbon from the oil faster than the air around can furnish oxygen to combine with it. Did you ever hear of an Argand lamp or an Argand burner?"

John said he had, but Flippy did not remember whether he had or not.

Lawrence then went on to explain the very simple contrivance which was invented by a man named Argand for supplying a double current of oxygen to the wick of a lamp, and also supplying it faster, so as to consume completely a much larger quantity of carbon than would otherwise be possible.

This contrivance consists of making the wick cylindrical, and admitting the air on the inside as well as on the outside of it, and then, by placing a glass chimney over it, producing a draft by the ascending current of air, which has the effect of bringing the supply of air in faster.



ARGAND BURNER.

The engraving shows how this is done. The wick is seen in the centre, the middle arrow below showing how the air passes up and supplies oxygen to the inside surface of the flame. The other arrows show how it passes up to supply the outer surface. H is the glass chimney which creates the draft, and K the brass tube in which it is set to hold it firm.

"This contrivance," continued Lawrence, after he had explained it to the boys, which he did by rolling up two pieces of paper and placing them together in such a way as to represent the form of the wick and the relative positions of the wick and the glass, "was found to work admirably, and it has been applied to a great number and variety of lamps and gas-burners. And whenever you see a light managed on this principle—

that is, with the flame, whatever produces it, in a cylindrical form, with a current of air on the inside as well as the outside of it, and a glass chimney to increase the draft—you may pretty safely infer that it is an Argand burner."

Just at this moment it struck "eight bells," which showed that the captain had decided from his observations, or in some other way, that it was noon where they were, though only a little more than half past eleven by the time which they had brought with them from the noon of the day before. A moment afterward a bell rang for luncheon, and Lawrence and the boys rose to go below. They would have been obliged to go below at any rate without this summons, for the fog and the clouds had become more dense, and a misty rain was falling upon the decks. In the course of the afternoon the wind rose, and the ship soon began to move uneasily through the water, indicating that the sea was growing rough. There were fewer persons at dinner that day, and fewer still at tea. The motion increased in the evening, and Lawrence recommended to John to climb up into his berth at an early hour, so as to get asleep before he became sick. John was very ready to do so.

He slept soundly for some hours, but at length he was awaked by a loud trampling over head. He opened his eyes, but it was almost entirely dark, and so he knew that it was after twelve o'clock. The candle which burns in a little closed box, with glass sides, between each two staterooms, is always put out at midnight, unless in special cases an arrangement is made for burning it through the night.

He listened, and heard the shrill whistle of the boatswain, and the song or chant of the sailors, indicating that they were "heaving away" at something or other.

John put his head over the edge of his berth, and looked down to see if he could tell whether Lawrence was awake.

"Lawrence," said he, "are you awake?"

"Yes," said Lawrence.

"What do you suppose they are doing on deck?"

"Making sail, or taking in sail," said Lawrence, "or something or other of that sort. It is all right, I've no doubt."

So John lay down again. But in a moment more he heard the shriek of a steam-whistle a great way off forward.

"Lawrence," said John, "what do you suppose that whistle means?"

"Perhaps it is the boiler whistling for more water," said Lawrence.

"Nonsense!" said John. "The boiler would not whistle for water."

"Yes," replied Lawrence, "they have a contrivance in some boilers by which, when the water gets too low, there is a float that settles down, and opens a valve, and lets steam out to whistle for them to pump in more water."

"No," said John, "that isn't the plan in our boiler. They have a glass tube. The engineer showed it to me."

"Then perhaps it is the fog," said Lawrence. "They may be afraid that there is an iceberg ahead, in the fog."

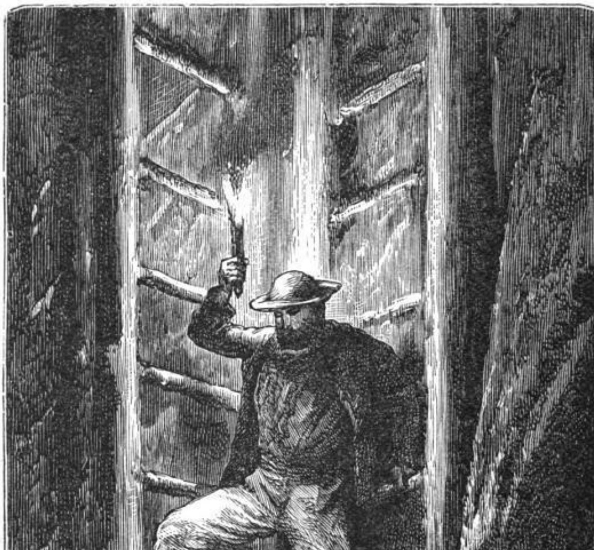
"That would not do any good," said John. "An iceberg would not get out of their way for whistling."

"Then perhaps there may be fishing-boats," said Lawrence, "and they want to warn them that we are coming."

"It *may* be that," said John.

"At any rate, it is nothing to us what it is," said Lawrence, "so lie down and go to sleep."

So John lay down and went to sleep, and slept soundly till morning.



GOING DOWN BY LADDERS.

CHAPTER XVI.

MISS ALMIRA.

"Flippy," said Lawrence one day to Flippy, as he and the boys were sitting at the table after tea, talking together on various subjects, "do you mean to go down into a coal-mine when you get to England?"

"Yes," replied Flippy, "indeed I do—that is, if I can get a chance. Wouldn't you?"

"I think I should," replied Lawrence. "At any rate, I think there would be more sense in it than in your getting the stokers to let you down into the coal-hole on board ship. But how do you intend to go down? There are two or three ways. You can go down as the workmen do, or as visitors do."

Flippy wished to know what the different ways were.

"You can go down as the workmen do sometimes," said Lawrence, "in a kind of an iron tub."

"Like the bucket for the cinders here?" asked Flippy.

"Yes, only bigger," said Lawrence; "it is big enough, usually, to hold several men."

"And what are the other ways?" asked Flippy.

"The officers and managers of the mine generally go up and down in a kind of iron cage, which is cleaner and more comfortable, and also safer than the tub. Then there is another way still, which the workmen use sometimes and in some places, and that is by ladders."

"That's the way I'll take," said Flippy, eagerly. "I should like to go down into a mine by a ladder."

"It would be hard work," said Lawrence. "The mines are, some of them, very deep. But, whatever way you take for going down, there is one thing that I think is important, and that is that you should learn all you can about coal before you go. The more you know about it, the more interested you will be in seeing it. And, if you like, I will tell you something more about it now."

The boys said that they should like to hear.

"Well, then, said Lawrence," when you go down into a mine, and see the men heaving out the coal, and blocks of it lying about, you must think that each lump that you see contains a certain amount of heat *in reserve*, or, rather, the power of giving out a certain amount of heat when the carbon and hydrogen contained in it is combined again with oxygen. It has the power to produce a certain amount and no more. You can not possibly burn it in any way to prevent its giving out so much, and you can not possibly burn it in such a way as to make it give out more."

"Yes," said Flippy, "you can blow it with the bellows. When a blacksmith blows his fire with the bellows he makes it a *great deal hotter*."

"True," said Lawrence, "he makes the fire hotter, but does not he make the coals burn out faster?"

"Yes," said Flippy, "of course the coals burn out faster."

"So you see there is no gain in the amount," replied Lawrence, "but only an increase of *intensity* by shortening the *time*. You can have your heat all at once by carrying on the combustion very rapidly, or you can make the combustion go on more slowly by not sending in a rapid supply of oxygen, and so have a lower degree of heat continued for a longer time. It has been proved by the most careful experiments that the whole amount developed by the same quantity of fuel, whether it is burned fast or slowly, is exactly the same."

COAL-MINER AT WORK.

"And there is another thing that is very curious," continued Lawrence, "and that is, that this amount of heat which coal or any fuel gives out in burning is exactly the same as that which was expended by the sun in the leaves of the plants in producing the vegetable substance out of which the coal was formed; that is to say, the carbon and oxygen, and the hydrogen and oxygen, in *coming together again* in burning, give out precisely the same amount of heat with that which they absorbed from the sun *in being separated.*

So, when you take a walk in the woods in a hot summer's day, and find how cool it is, it is curious to think that the heat of the sun that has disappeared among the trees is not lost, but is laid up, as it were, in the wood, the sun having expended it in separating the carbon from the oxygen, and that it will all come out again when the oxygen is restored. Thus a farmer, if he only understood what was going on about him when walking through his wood-lot in June and July, and finding it so cool under the trees, would not only enjoy the coolness at the time, but would take pleasure in thinking that the sun was laying up all that surplus heat in the wood, to come out again in due time to cheer his fireside with the glow of its brightness and warmth in the long evenings of December and January."

Now it happened that while Lawrence was talking in this way to the boys, there was a young lady sitting at the table a little way beyond him, reading. Lawrence had become informally introduced to her some time before through the major; or, rather, he had not been introduced to her at all, but had formed part of a group with her, who were engaged in conversation, and which both she herself and Lawrence joined. They had continued this acquaintance by meeting on several subsequent occasions.

It is necessary to be very careful, in making acquaintances on board such a steamer as those traversing the Atlantic, to have decisive evidence of *some kind* in regard to the respectability and character of the persons you are to associate with. But it is not at all necessary that this evidence should come in the form of a regular introduction, nor, indeed, would this be generally possible. The company of passengers come together, in general, as total strangers to each other, and with no mutual acquaintances, so that formal introductions are, in general, out of the question. If the passengers were to enjoy no social intercourse except so far as they could be regularly introduced to each other, they would form a very morose, exclusive, and unsocial company all the voyage.

When Lawrence found that the young lady was inclined to pay attention to what he was saying to the boys, he turned toward her, and said that he had been whiling away some of the time of the voyage in giving the boys some instruction on the subject of combustion and heat.

"Yes," she replied, "I have been very much interested in what you said about the heat from the sun being stored up in trees and plants. I always supposed that it was the *shade* that made it cool in the woods."

"It is the shade in part, I have no doubt," said Lawrence, "and it is also in part owing to the evaporation of the moisture on the surface of the leaves and on the ground; but it is owing still more to the *absorption of the heat of the sun* by the leaves in the formation of vegetable substances. The heat remains concealed in some mysterious way in the substance of the plant, and entirely suspended in its action, as heat, until it is afterward liberated by combustion."

Lawrence then went on to explain briefly to Miss Almira—for that was the name by which he addressed her—what he had taught the boys about the process of vegeta-

ANCIENT VEGETATION (Ideal Landscape).

tion being substantially a process of separating carbon and hydrogen from oxygen by the power of heat and the other radiants from the sun, and that combustion was nothing more than the violent *return of the oxygen* to its former combination with them, thus releasing and setting free the forces which had been derived from the sun and were stored up in the wood or the other vegetable substances.

"So you see," said Lawrence, "that the sun in the summer pours his beams over all the forests and fields of our hemisphere, and deposits a vast portion of his heat and force in the plants and trees which he has made to grow there. When, in the fall, he goes south of the equator, he leaves all this heat and force behind him, to help us against the cold which comes from the north to occupy his place while he is gone. In the same manner, in one age of the world he makes vast deposits of his power in forms of vegetation very different from those of the present day, growing in swamps, and morasses, and in grounds half submerged, so that, when they fall, they fall into the water, and are in a great measure protected from decay. There they in time form vegetable strata of considerable thickness, and when at last, in another age, these strata, through some changes in the surface of the land, become covered with strata of sand, or clay, or gravel which the flow of water forms over them, and which afterward become strata of rock, the vegetable strata become converted into beds of coal, with all the heat and power which they derived from the sun still stored in them; that is to say, they consist of carbon and hydrogen which has been, by great force, separated from oxygen, and which still have a great tendency to combine with it; and they do this, when the conditions are right, with great force and with the evolution of great heat, which force and heat are precisely the same in amount that the sun expended in forming them."

Miss Almira was greatly interested in these truths. She was well qualified to understand and appreciate them, for in her mental constitution, as we often find to be the case with young ladies of her age, were combined the characteristics of poetic feeling and of scientific exactness and precision. In other words, she was capable of both thinking clearly and feeling deeply. And the idea of such a vast process as that of the treasures of heat from the sun being slowly deposited, year after year, century after century, and age after age, until the vast accumulations of power which lie stored in the great coal deposits of England and America were formed, and of their lying there stored as immense magazines of power for thousands and thousands, and even perhaps millions of years, and then of the ingenuity of man in finding them and penetrating to them at the enormous depths at which they lie, and raising them to the surface, and bringing out the stored force and using it to do all his heavy work—to grind his corn, to weave his cloth, to heat his furnaces, to warm his rooms, and transport him by sea and by land all over the globe—filled her mind with wonder and delight. She not only saw and enjoyed the precision and beauty of the scientific principles involved, but her heart was filled with an emotion akin to awe in the contemplation of the inexpressible grandeur of such a process.

THE STORED FORCE RECOVERED.

CHAPTER XVII.

MEASUREMENT OF HEAT.

MISS ALMIRA could perceive and understand nice scientific distinctions, too, when they were pointed out to her, as well as feel the sentiment of poetic grandeur and beauty. An instance of this occurred in the course of the conversation which took place at the time referred to in the last chapter. Lawrence had occasion to speak of the difference, in a scientific point of view, between temperature and heat. He said that every pound of coal of the same quality—that is, containing the same amount of carbon and hydrogen, would give out, in combustion, the same amount of heat, or, as he expressed it, the same number of *units of heat.* She asked him what he meant, exactly, by units of heat. He replied by asking her if she had ever read or heard how heat was measured. She said by the thermometer, she supposed.

Lawrence replied that the thermometer measured, or, rather, indicated heat in a certain popular sense, but that, strictly speaking, the thermometer only made known the *temperature* of a substance; and that by the temperature of a substance was meant its state or condition in respect to its power of *communicating* heat to other bodies, and had no necessary reference to the quantity of heat which it really itself contained.

This is a very important scientific distinction, and one which a great many persons, even better informed than Miss Almira was, do not understand. It is somewhat difficult to understand this distinction—indeed, almost impossible to do so unless the mind is endued with something of that capacity for precise and exact thought which Miss Almira possessed.

You can, however, begin to make a separation of the two ideas in your mind by considering that there must be twice as much heat in respect to quantity, in two gallons of boiling water, as there is in one; and yet the *temperature* of two gallons boiling is the same as the temperature of one. This shows that the expressions *temperature* and *quantity of heat* stand in our minds for two very different things.

Temperature is the condition of any substance in respect to its *tendency to impart heat to surrounding bodies.* When the temperature of a body is low compared with that of other bodies around it, as, for instance, in the case of ice, in an open summer air, or in a glass of water, we may regard it as having, in a certain sense, the *same disposition* to part with its heat as it has when surrounded by a medium much colder than itself, as, for instance, where ice at 32° is surrounded by an atmosphere at zero; but this disposition, or tendency, is in the former case overborne by the superior temperature—that is, the superior tendency to part with heat—of the air or water surrounding it.

Thus the measure of the temperature of a substance is only the measure of its *tendency to receive or impart heat* as compared with other bodies. It does not determine at all what quantity of heat the substance in question has received in bringing it to that condition; for it may be larger or smaller, and so may have a greater or less quantity to part with, or it may have imbibed a great quantity which remains latent in it—that is, which is in such a condition that it has no tendency to part with it. We measure temperature by thermometers; but as to the actual quantity of heat which any substance has received to bring it up to any particular temperature, that is a very different question, and must be determined in other ways.

In order to impress more fully on Almira's mind the difference between the ideas of *temperature* and *quantity of heat*, Lawrence varied his illustration of two gallons and one gallon of water by referring to the great smoke-pipes which ascend from the furnaces through the decks, and which the passengers were so much in the habit of warming themselves by in cold and chilly days.

"I suppose," said he, "that those chimneys are about as hot as common iron stoves are made in warming a room, for they are not red-hot, and they are too hot to touch with the hand. A thermometer, therefore, would indicate the same temperature for the smoke-pipe and for the stove; but the quantity of heat that the smoke-pipes give out must be enormously greater than could come from any stove, on account of their enormously greater size."

"I see that," said Almira, "but I don't see how that quantity can be measured."

"That is a great difficulty," said Lawrence, "and for a long time it seemed to be an insurmountable one. There was a double difficulty, in fact. First there was no unit of measurement to apply, and, in the second place, there seemed to be no means of applying it if there were one."

Lawrence then went on to explain that in all measures there must be *a unit of measurement*, as it is called, which is a certain convenient quantity of the substance to be measured, assumed for the purpose. Thus, in the measurement of lines, a foot is the usual unit of measurement for certain magnitudes, and a yard, a mile, or an inch for others; so an hour, a month, or a year are units of measurement for time.

Now we have names for all these units, and that helps to make them seem very simple, for giving a thing a distinct name has a wonderful effect in simplifying the conception of it to our minds. If we had no name for a foot, but were obliged to designate it as a unit of measurement for length, denoting a quantity equal to the distance from the heel to the toe of a full-sized man, and none for fathom, but were obliged to describe it as a unit of measurement for depth determined by the portion of a sounding-line which a man can draw up at one reach between his two arms, we should see at once how arbitrary those units would be; and it would, moreover, be much more difficult to think and reason about them than it is at present.

Now, in respect to the measurement of *quantities of heat*, it is necessary, in the same way, to take some arbitrary quantity of it, as a unit, to measure by. For instance, we place a large caldron over a fire; a certain quantity of heat passes up every minute, through the iron, into the caldron. This quantity may be measured. It may be very difficult to measure it in some cases, just as it is very difficult sometimes to measure the exact length of a line running over a very rough or very marshy piece of ground. But we can *conceive of its being measured*—the quantity necessary to raise the temperature of one pound of water one degree being taken as a standard.

It is plain, moreover, that putting a thermometer into a substance, whatever it may be, that is in the caldron, will not answer at all as a means of making this measurement. The thermometer, in such a case, would show how *hot the substance had become* at the time of applying it, but it would not show at all what quantity of heat had passed up through the iron in each minute to make it so hot. It would not necessarily enable us to determine this if we knew how hot the substance that the kettle contained was at the commencement of the experiment; for the increase of temperature in the contents of the kettle, though it would depend a great deal on the amount of heat coming into it from the fire, would not depend entirely on that, but on many other considerations, such as what the substance was, whether water, or solid ice, or oil, and many other circumstances.

Indeed, we can scarcely infer at all what quantity of heat any substance has absorbed from its temperature; for, in the first place, it is found, curiously enough, that some substances are much hotter—that is, their temperature is raised much higher than others by the absorption of the same amount of heat.

And then, in the second place, there are cases in which a very large amount of heat may be communicated to a substance without making it any hotter—that is, the heat is expended in making other changes in its constitution, and does not raise its temperature at all.

When Lawrence had gone as far as this in his explanation, he found that Flippy was beginning to look a little tired, for such general explanations were a little too abstruse for him, and so he thought he would illustrate the subject by a kind of story.

"There is a kind of an experiment that you can perform yourself, Flippy," said he, "to make this very clear. I will tell you how some boys tried it who were not afraid of the cold."

"I'm not afraid of the cold," said Flippy.

"Ah! but this was tremendously cold," said Lawrence. "It was in Vermont, on a moonlight night in January, and the thermometer was 20° below zero."

"I should not care if it was fifty below zero," said Flippy.

"It is sometimes as cold as that, and even colder," said Lawrence, "in the Arctic regions; but it was only 20° below zero when these boys made their experiment. They took a thermometer, and a lantern, and an iron kettle, and went down to a small pond beyond their garden, or, rather, they went to a place where there was a small pond in the summer; but now it was frozen, over two feet thick, and covered with snow two feet deep. They waited a few minutes for the thermometer to get cold, and then looked at the mercury, and found that it was 20° below zero. Then they filled their kettle with snow, and put the thermometer into that, and, after leaving it there a few minutes more, they looked again, and found that the mercury stood at *eighteen degrees* below zero. They thus ascertained that the snow was not quite so cold as the open air. They then returned toward the house, bringing the kettle full of snow with them. They left it in the back kitchen, and then, after putting away their lantern and taking off their coats, they went into the parlor and sat down to their reading."

Flippy seemed much interested in listening to the story, but said he did not see what the boys did all that for.

"You'll see presently," said Lawrence. "There had been no fire in the back kitchen where the boys left their kettle of snow, and so it was very cold there; but it was not nearly so cold as it was on the pond. It was only 2° below zero there. So, while the snow was at 20° below, the air in the room was only 2° below, and, of course, the snow began to grow warmer."

"Warmer," repeated Flippy; "snow can't be warm at all."

"Well, less cold, then," said Lawrence. "When any thing is less cold, we call it warmer in science, but it means the same thing. To make it less cold, it had to receive a certain quantity of heat from the air in the room. This the boys found to be the fact, for they came out into the back kitchen in about half an hour, and tried their thermometer in the snow again. They found that the snow had received a quantity of heat from the air in the room sufficient to raise its temperature to 4° below zero —nearly, but not quite, up to the temperature of the air in the back kitchen.

"Then they carried the kettle of snow into the front kitchen, and put it on the stove. It was now in a condition to receive heat much faster than before, for there was a fire in the stove, and, when the kettle was put in its place, the bottom of it came almost in contact with the fire. The boys left their snow in this position for about eighteen minutes, and then, trying their thermometer in it again, they found that it had risen to 32° *above* zero. Thus, inasmuch as it was 4° below zero when they brought it in, it had received a *quantity of heat* from the fire sufficient to raise the temperature about thirty-six degrees. The snow was, in fact, beginning to melt quite fast.

"The boys then went away again and remained half an hour, leaving the kettle with the snow in it over the fire. After they had waited for half an hour, they came back. They found that the snow was now nearly all melted; but when they put the thermometer in, to try the temperature, they found that it was still 32°—just what it was before!—that is, although the fire in a quarter of an hour had raised the temperature of the solid snow thirty-six degrees, yet in *half an hour*, though there was the same fire, and the same quantity of heat going in all the time through the bottom of the kettle, the temperature had not been raised at all.

"This was wonderful to them. They had read that it would be so in their books, and they had tried this experiment to test the question. It seemed to them very singular that all that quantity of heat passing up into the melting snow should not warm it—that is, should not raise the temperature at all.

"The explanation is, that all this quantity of heat, which was enough to have raised the temperature of *water* a great many degrees—high enough, in fact, to make it scalding hot, if it had been able to employ itself for that purpose—was really employed in *changing ice into water*, for snow is only ice in thin flakes; that is to say, it was employed in making a change in the *internal constitution of the substance*, and not in *raising its temperature.*

"The boys left their kettle of water again and went back to their reading; the thermometer indicated 32°. But when they left the kettle this time the ice was all melted, and thus the heat, having now no more work to do in changing the internal constitution of the substance, could expend its force in raising the temperature of it, and it began to grow hotter very fast. In fact, when the boys came back, half an hour later, the water was boiling—that is, the temperature of it had been raised to 212°."

"Then they must have spoiled their thermometer in putting it in," said Flippy.

"Oh no," said Lawrence; "they had a kind of thermometer which the chemists use. The scale turns back out of the way when you wish to put it into snow or water."

"Is that story true?" asked Flippy, after a moment's pause.

"No," replied Lawrence, coolly.

"Then you made it up," said Flippy.

"Yes," said Lawrence, "in order to let you see clearly, and have fixed in your mind, the distinction between the idea of *temperature* and that of *quantity of heat*, and understand that a thermometer, though it may measure one very correctly, tells us nothing at all about the other."

"It helps *me* to understand it very much," said Almira. "Indeed, I never understood it at all before. I always imagined that, somehow or other, the thermometer measured the quantity of heat."

"I understand it pretty well myself," said Flippy, "but I would rather that the story should have been true."

"You can *make* it true," said Lawrence, "by trying the experiment yourself some time next winter."

"I mean to do it," said Flippy, "if I can only get that kind of thermometer."

Lawrence went on to state again, as he had done once before, that in measuring and noting quantities of heat, it was necessary to assume some particular quantity as the measuring unit. The unit used for this purpose in English-speaking nations is the amount *required to raise the temperature of one pound of water one degree of Fahrenheit's thermometer.* This is called the English unit of heat.

I advise all the readers of this book to fix this very firmly in their minds, namely:

The English unit of heat is that quantity of heat which is expended in raising the temperature of one pound of water one degree.

The French, who have a different standard of weight and a different thermometer from ours, have a unit of heat on the same principle, though adapted to their measures. It is the quantity expended in raising one *kilogramme* of water one degree of the *Centigrade* thermometer. They call their unit of heat a *calorie.* We, the English-speaking people, have no name for ours; we call it simply the unit of heat.

Thus, if we were to put a red-hot iron ball into a pail which contained ten pounds of water, and, after letting it remain until it was as cool as the water, if it should then be found that the water was made three degrees warmer by it, then there would have passed from the ball thirty units of heat, for ten pounds of water would have been raised three degrees each, which makes thirty.

It makes no difference how warm or how cold the water was at the commencement, for it is found, by means of very curious experiments, that within a very wide range of units it requires practically the same quantity of heat to raise the temperature of water one degree, whatever its temperature may have been before.

So the way to determine how much heat is given out by a lamp burning an hour is to contrive some way to find out how many degrees it will warm a given quantity of water.

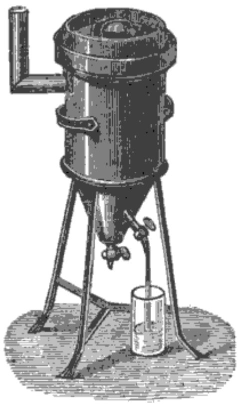
"I do not see how they can do it," said Almira, when Lawrence had made this explanation; "for I don't see how they can manage to make *all* the heat from a candle, for example, or from any other fire, go into the water. Some of it would escape in other ways."

"They arrange it so that there shall be water all around it," said Lawrence. "Of course they have to contrive a special apparatus for the purpose, so that what is to be burned shall be inclosed in water, and the pipe by which all the products of combustion pass away shall make a circuit in the water till the gases and fumes are entirely cool.

"But another still more curious way," he added, "to find out how much heat is produced by the combustion of a given substance is to burn it inclosed *in ice.* They make a vessel of sheet-iron, the sides of which are double, with quite a space between. Inside the inner vessel they have something to hold the substance which they wish to burn, and put all around this a quantity of pounded ice, so as to fill all the space in the inner vessel not occupied by the receptacle for the fuel and the air-passages communicating with it.

"They also fill all the space between the double wall of the vessel with ice. Of course there is an opening below to admit air to the fire, and a pipe above to allow the gases to escape, after they have been carried round and round in a spiral pipe till they have become cool.

"In this way all the heat which is produced by the combustion is spent in melting the ice. The water that is thus produced is drawn off afterward by a pipe and faucet below, as you see in the engraving. They weigh this water, and so find out how much ice the heat produced by that burning has liquefied; but to melt ice, as has been found out in other ways, requires 140 units of heat—that is, it requires as much heat to melt one pound of ice as it would to raise the temperature of the same weight of water 140 degrees, or to raise the temperature of 140 pounds of water one degree. So, from the quantity of water which they get by the faucet in the apparatus above described, they can tell by an easy calculation how many units of heat—that is, *what quantity*—was produced by this combustion."



QUANTITY OF HEAT.

As Lawrence said this, he drew a small portfolio out of his pocket, and made a little drawing upon a piece of paper which he took from it, to show the party the form of the apparatus which he had described.

Almira and the boys were all quite interested in looking at the drawing, and Almira asked Lawrence if he would allow her to keep it.

"No," said Flippy, "*I* want it—to put into my journal."

"Very well," said Lawrence; "Flippy may have this one, and I will make for you another, Miss Almira, and will give it to you to-morrow.

"Only remember, boys," he added, "what the purpose is which it is intended to effect, namely, to determine what *quantity of heat* is developed in any particular process of combustion, by showing *how much ice it will melt*, there being 140 units of heat required for every pound of water produced by the melting."

CHAPTER XVIII.

PERSONALITIES.

Lawrence gave Flippy the little drawing, and then said that he had talked long enough—too long, he was afraid—and so they would go up on deck and see what was to be seen there.

But, before we let them go, let me give you a recapitulation of what he had explained to them, so that you may have it well fixed in your minds. It was this: The thermometer does not measure quantities of heat at all. It only shows to what condition, as to heat, any substance has reached; it tells us nothing about the quantity of heat which it has received to bring it to that condition. These quantities are estimated in what are called units of heat, the English unit being the amount necessary to raise the temperature of one pound of water one degree.

You must remember, too, that the quantity of heat which can be produced by burning any particular amount of any kind of combustible is fixed, and can not be increased or diminished. The reason is, that it contains only a certain quantity of carbon and hydrogen, and that that quantity of carbon and hydrogen can only combine with a certain fixed quantity of oxygen, and that, in so combining, can only give out a certain fixed amount of heat. You can make it give this quantity out faster or slower by blowing or not blowing the fire—that is, by supplying it with oxygen more or less rapidly. Thus you can get a heat *more intense in degree* by increasing the rapidity of the combustion, and so shortening the time. In other words, you can raise the temperature for a time, but you can not increase the total quantity of heat that the combustion will produce.

It is necessary that the reader should clearly understand this last point, not only because it involves a fundamental principle in the science of heat, but also it is necessary to enable him clearly to comprehend a conversation which subsequently took place between Flippy and his mother, as will be related in due time.

When Lawrence had finished the conversation related in the last chapter, Almira thanked him for the information which he had given her, and asked him if he was willing, the next time he had a conversation with the boys on such subjects, to allow her to be present too. To this request Lawrence readily acceded. Indeed, he was much pleased to find that Miss Almira took an interest in such investigations.

So Lawrence and the boys went on deck, while Almira took out her journal to write an account in it of the conversation which she had had with Lawrence, and to make a brief summary of the principles which he had explained, in order to fix them in her mind. She left a place on the page to gum in the little drawing which Lawrence had promised to make for her, to illustrate the manner in which quantities of heat could be measured by the quantity of ice melted, at the rate of 140 units to the pound.

Lawrence and the boys went on deck. They walked forward and looked all around to see whether there were any sails, or steamers, or icebergs in sight.

"I wish we could see an iceberg," said Flippy. "My mother says she wants to see one very much."

There was, however, nothing to be seen. Accordingly, after looking about for a little time, they all three sat down upon a large cushioned sofa which was placed against the paddle-box. There were a great many other people sitting in different places on the decks, some upon folding chairs, and some upon camp-stools, while others were walking back and forth along the decks for exercise.

"We've got another member of our class," said John.

"Yes," said Lawrence, "and I'm very glad of it."

"I'm glad too," said John; "but what is her other name besides Almira?"

"I don't know," replied Lawrence; "I did not hear her other name."

"How do you like her?" asked John.

"I like her very much," replied Lawrence. "She has mind and soul both."

"What do you mean by that?" asked Flippy.

"Why, that she has both head and heart; and that is not true of every girl."

"I don't know about heart," said Flippy, "but I never saw any girl without any head."

John laughed, and then asked Lawrence if he knew where Miss Almira was from. He said no, but he thought she was from somewhere in the interior of the country. John said he did not think she looked like a country girl at all. Lawrence replied that if he meant by that to say that she had the appearance and manners of a lady, he agreed with him entirely.

"She has evidently been accustomed," he said, "to cultivated and refined society, but she does not appear like the girls who have spent all their lives in the great cities, where they pass their time in such a continual whirl of excitement and pleasure, poor things! that they have no time to acquire habits of quiet reflection. They are very brilliant, and are charming sometimes in light conversation. They are very intelligent, too, in their way. But they are not generally so thoughtful and considerate as the country girls, and do not listen so calmly and quietly to what they hear. They half hear it, and then away their thoughts fly to something else."

I think myself that Lawrence was somewhat too sweeping in the expression of his opinion of the comparative intellectual characteristics and habits of thought of city and country girls, though there may be some ground for the distinction which he made, inasmuch as those who are brought up in the country are much more alone, and have much more time and opportunity for quiet reflection than those who spend their lives amidst the constant bustle and excitement of great cities; and it is very natural to suppose that these differences in the influences operating upon them respectively should, in many cases, produce a difference of result.

The next evening after this, when Lawrence went to his state-room to go to bed, a little while after John had retired—for there was not room in the state-room for them both to undress together—John looked down from his berth, which was the upper one, and said,

"Are you going to turn in, Lawrence?"

The phrase for going to bed at sea is "turning in." It *is* turning in, literally, for, in order to get into your berth, you have to put your head in first, and then give a peculiar kind of roll over, which could not be so well described by any other words as by "turning in."

"Yes," said Lawrence; "it is about time."

"I'm sorry I've turned in," said John.

"Why?" asked Lawrence.

"Because I'm not sleepy," said John; "I could not go to sleep if I were to try."

"It takes a wise man, and a still wiser boy," said Lawrence, "to tell when he can and when he can not go to sleep. Lie down and shut your eyes, and very likely you'll be asleep before you know it."

John lay down for a moment, while Lawrence continued his preparations for going to bed; but soon he raised his head again and said,

"I think it likely that Almira may like you well enough, but I don't believe that Mrs. Gray does."

"What makes you think so?" asked Lawrence.

"Because Flippy told me that she said she thought you was a pedantic boor."

"A pedantic boor!" repeated Lawrence. "That's expressive, at any rate. I'm glad you told me that that's the opinion she has formed of me. I'll see if I can't make her change it."

"How will you do it?" asked John. "If I were you, I would not speak to her all the voyage."

"I'll try a better way than that," said Lawrence.

"What is your way?" asked John.

"I'll wait till I've tried it," said Lawrence, "before I tell you what it is. If I succeed, then I'll tell you all about it."

Now, although Lawrence said that he was glad to hear what Mrs. Gray had said of him, it was a mistake of judgment on John's part to repeat it to him; for it is a general, indeed an almost universal rule that we ought not to report to our friends any evil that we may have accidentally learned to have been said of them by other people, as it only tends to vex and irritate them, and to increase and perhaps perpetuate an alienation and ill feeling which might otherwise have been only momentary. Generally, when people hear such things, it awakens resentment and anger, and leads to a retaliation which only makes the matter worse.

But Lawrence had taken great interest in studying the movements and operations of the human mind, as well as those of the forces of external nature, and he knew very well that such expressions as Mrs. Gray had applied to him, and the feelings which prompted them, often arose, in the case of such persons as Mrs. Gray, from the most frivolous and insignificant causes. He had no doubt that Mrs. Gray's expressing herself so unfavorably arose from some accidental impression made by what he had said or done on some occasion, and that the way to remove that impression was for him to seek some opportunity of making another and better one. He took great pleasure in the idea of attempting to do this by the appropriate means, as an experiment upon mind—an experiment of a kind much more interesting than those made upon matter, on account of the greater delicacy of the "forces," as he called them, with which he had to deal.

The circumstances under which Mrs. Gray had called Lawrence a pedantic boor were these: On the evening before the conversation between Lawrence and John in their state-room, as above described, Flippy went to a part of the saloon where his mother was sitting with another lady, doing some kind of crochet-work.

"Well, Flippy," said his mother, "it is about time for you to go below and go to bed. Have you had a pretty good time to-day?"

Flippy said he had had a very good time.

"I see you have been talking with Mr. Wollaston a good deal to-day. He does not take any notice of me whatever. I think he is very rude."

Flippy said he did not think he was rude at all.

"Oh no!" said Mrs. Gray. "I dare say he has been very polite to you. And what new philosophical nonsense has he been teaching you to-day?"

"No nonsense at all," said Flippy; "but he has taught me something that I never knew before, and that is, that there is only so much heat to be got out of a pound of coal, no matter how you burn it."

"Well, I'm sure that is nonsense," replied Mrs. Gray, "if there is any such thing. All the world knows that you may make the same fire a *great deal* hotter by blowing it with the bellows. Any blacksmith's boy could tell him that."

"Yes, mother," said Flippy, "the fire is hotter for the time, but there is no more heat, in all, to come out of it."

"Nonsense, Flippy!" said his mother. "To say that it is hotter is only another way of saying there is more heat. I think your Mr. Lawrence, as you call him, is a pedantic boor." So saying, she turned to the lady sitting by her side, and said, "Just hear, Caroline. There is a young man who pretends to be a great philosopher, and he says you can't make a fire any hotter by blowing it with the bellows!"

Here Mrs. Gray laughed aloud, and the other lady joined her.

"Was there ever any thing so absurd?" said she.

Here the two ladies laughed so much that the crochet-work was entirely interrupted.

Poor Flippy, as might have been expected, was silenced, but not convinced. Indeed, although he had a tolerably clear idea, for such a boy, of the distinction between the whole quantity of heat which the combustion of the coal could be made to render, and the intensity, in respect to temperature, to which the combustion could be urged by hastening the rapidity of it, he could not explain it to his mother very well, and so he wisely gave up the attempt. He stood silent for a moment, and then went away, and, by way of relieving his indignant feelings in some slight degree by giving them utterance, told John that his mother called his cousin Lawrence a pedantic boor.

It is not surprising that Flippy had not learned to feel any more interest in the cultivation of his mind and the acquisition of knowledge if he had been accustomed from infancy to receive from his mother so little help, encouragement, and sympathy as this.

Lawrence's idea that Mrs. Gray's unfavorable opinion, in respect to his gentlemanliness, implied in her calling him a boor, was derived from some accidental impression made upon her mind, which might very likely be easily removed, was very correct. The unfavorable impression arose from the fact that, while he had been comparatively quite intimate with Flippy, he had not paid any attention to her, Flippy's mother. Now, in such cases as this, of a voyage at sea, where persons are thrown together without means of regular introductions to each other, it requires a great deal of tact and judgment, especially on the part of *young* gentlemen, to draw the line between want of attention on the one hand and intrusiveness on the other. A gentleman is placed at the table, for example, next a lady whom he does not know, and is to sit next her every day for a week. Shall he speak to her? She may think, if he does, that he is forward and presuming. Shall he take no notice of her? She may conclude that he is very uncivil. Almost every gentleman, under such circumstances, often finds his situation for a time somewhat embarrassing, and, with the best intentions in the world, and the most sincere desire to do what will be most agreeable to those with whom he is thus thrown into association, is often at a loss what to do, and is exposed to be unjustly judged by ladies who do not properly consider the circumstances of the case. This was Lawrence's fate. He had no means of knowing whether Mrs. Gray would consider him entitled to speak to her on the ground of his acquaintance with her son, or would consider it an act of presumption on his part to do so. And she, because he did not do so, pronounced him a boor.

CHAPTER XIX.

THE ICEBERG.

THE next day after the conversation between Lawrence and John, related in the close of the last chapter, while Lawrence was reading in a folding chair under the lee of the mainmast, John came to tell him that there was a large iceberg in sight. It had suddenly come into view, through an opening in the fog, on the starboard bow.

Lawrence immediately rose and went forward to see it. He found that a number of passengers were assembled on the forward deck, and were scanning the iceberg with their glasses.

"Ah!" said Lawrence to himself, "here is an opportunity for me to make my experiment on mind."

"Flippy," said he, "where is your mother?"

Flippy said that he believed that she was in the saloon.

So Lawrence went down at once into the saloon, and there he found Mrs. Gray seated by the side of Miss Almira. Mrs. Gray had some embroidery-work in her hand, but Miss Almira had a book before her. They seemed, however, to be engaged in conversation when Lawrence went in.

Lawrence bowed recognition to Miss Almira as he approached the ladies, and then accosted Mrs. Gray, saying,

"Your son informed me, Mrs. Gray, that you had a great desire to see an iceberg, and there is one coming in sight now. I thought you would excuse my taking the liberty of coming to inform you."

"I am very much obliged to you, indeed, Mr. Wollaston," said Mrs. Gray, suddenly rising.

"You will like your opera-glass," said Lawrence; "perhaps it is better than mine. Can I get it for you?"

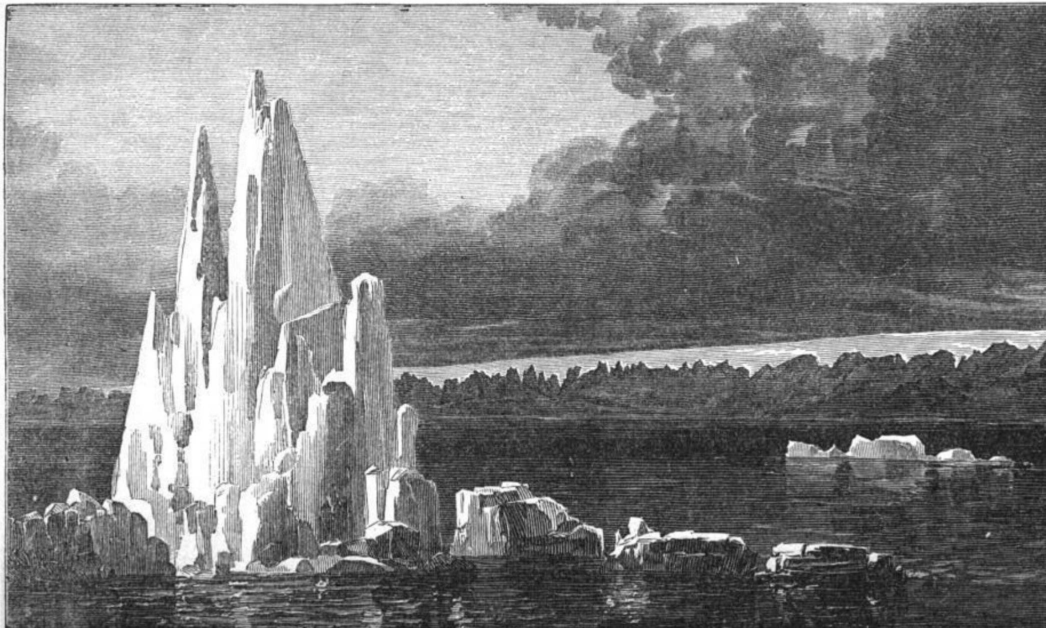
Mrs. Gray said that her glass was on the sofa, in her state-room; but she was sorry to trouble Mr. Wollaston to go for it. He said he could go in a moment. He knew where the state-room was, as he had often seen Flippy go in and out. So, after saying to Miss Almira that perhaps she would like to go too, he went down for the glass, and soon returned, meeting the two ladies at the door of the saloon.

He conducted them out upon the main deck, and thence up the flight of steps which led to the promenade deck above. He then led the way forward, offering his arm to Mrs. Gray, that she might aid her in steadying her steps in walking along the deck. Miss Almira walked by herself at Mrs. Gray's side.

Lawrence was polite and attentive to Miss Almira, but he devoted his chief attention to Mrs. Gray, as being the elder lady of the two. He thought that if Miss Almira was as sensible a girl as he had supposed her to be, she would understand this, and would not feel disturbed by it. Nor was he mistaken in this idea.

They soon came in sight of the iceberg, which was very large, and of a very grotesque and irregular form. This irregularity was caused by the different density of the different portions of it, arising from the manner in which it had been formed, taken in connection with the different action of the sea on the several portions of it, as it had been beaten and washed by the waves.

There is something very curious, and also very grand in the history of these icebergs. They are formed, in the first place, in a very wonderful manner. The vapors which are brought by the winds from the tropical regions give out their heat into the cold air of the arctic regions, and fall in



AN ARCTIC GLACIER.

rain and snow all over Greenland. They fall all over the land, and there—as, after once falling, they never melt, or, at least, only do so occasionally and in a very slight degree—a vast bed of ice is formed, which increases in depth year after year and century after century, until it forms a mass sometimes thousands of feet thick.

There would, indeed, apparently be no end to this accumulation in thickness were it not that, wonderful as it may seem, the whole mass has a constant onward motion, over the sloping surface of the country, toward the sea.

Such glaciers always have this slow motion where the ground on which they form is inclined. This is so wonderful that people were for a long time unwilling to believe it possible. But it is now abundantly proved to be true, not only in respect to the glaciers of Greenland, which in some places cover the whole country, but in Switzerland and the Tyrol, where they only occupy comparatively narrow valleys.

The movement is, however, very slow, from a few inches only to a few feet every day, according to the state of the weather and the slope of the incline. Thus you see very easily that ice formed in the interior of the country might be hundreds, and perhaps thousands of years in reaching the sea, all the time growing in thickness as it moves on. At length, as the advancing front of it reaches the margin of the shore, it can not stop, but is forced onward by the pressure of the mass behind it, until it gets crowded out over the water far enough to be broken off in immense portions by the floatage and by the force of the waves.

The masses thus cast loose get frozen in during the winter, and are imprisoned by the immense fields of sheet ice, five or six feet thick, which form upon the surface of the water over all the gulfs and bays in those regions. When the spring opens, the whole mass breaks up and is driven out by the winds and the currents down Baffin's Bay into the Atlantic Ocean in a stream of icebergs, floes, and vast fields of broken ice, which come on grinding and crashing together with a force and turmoil which it is frightful to witness, even in the daytime, and which it is still more frightful to hear at night, when the noise which they sometimes make is like a perpetual roll of thunder.

It is only by whalemen and adventurers in arctic exploring expeditions that these scenes can be actually witnessed; but persons who, like Lawrence and Miss Almira, have accustomed themselves, by habits of thought and reflection, to bring these vast movements and operations of nature home to their minds, can in some measure experience the emotions of awe and grandeur which they are fitted to inspire.

The groups that had assembled on the deck to see the iceberg seemed to be very differently affected by the spectacle. Some uttered exclamations of surprise and delight. Others began to make estimations in respect to its size, and its distance from the ship. Others were silent, and seemed to gaze upon the spectacle with solemn awe.

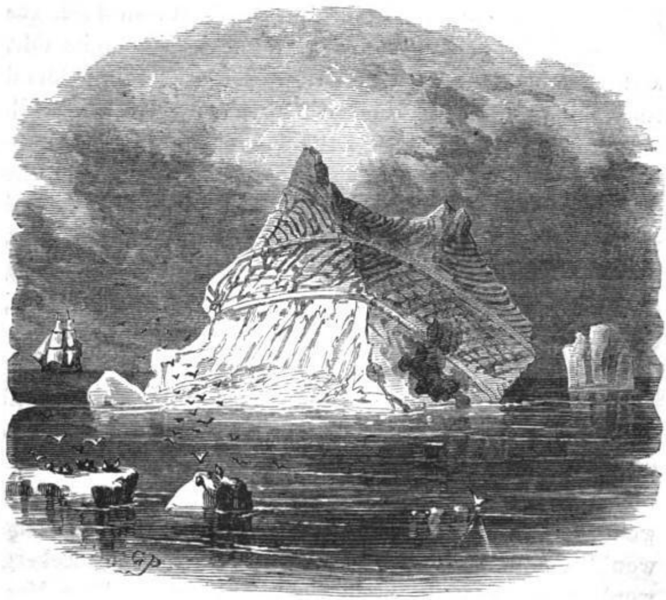
Mrs. Gray found her friend Caroline, as she called her, and, taking her stand by her side, she said,

"Wonderful! isn't it? It looks like a great camel."

"Oh no!" said her friend; "it looks more like a fortification, with a great round tower in the middle—all in ruins."

"Now *I* think it looks more like a camel," said Mrs. Gray. "That is not like a round tower. That is the camel's hump."

Miss Almira had withdrawn a little way from the rest, and stood gazing at the iceberg in silence. Lawrence had explained to her the evening before how these mountains of ice were produced, and her imagination was busy in pic-



THE ICEBERG.

turing the process by which the immense mass was formed far in the interior of Greenland, where the foundations of it had been laid perhaps a thousand years ago, in a fall of snow, or hail, or freezing rain, high up on the slope f a mountain side. As its thickness gradually increased by new accumulations, it began to acquire weight, and slowly to work its way down the incline. She imagined the vast field in this way slowly advancing on its course year after year, and century after century, through long arctic nights of stillness, solitude, and cold, the idea of which filled her with awe. She thought of the duration and grandeur of this slow but irresistible progress to the sea—of the sublime launching there of the fragment which formed the iceberg now in view—breaking off, as it must have done, from its attachment to the mass behind it with a sound like the crash of thunder—and then of its rolling over upon its side, and swinging to and fro with slow oscillations till it found its proper equilibrium—and of the waves which it set rolling off in all directions over the bay.

At this moment, happening to turn her face a little, she saw that Lawrence was standing at her side. They looked at each other with a smile of recognition and sympathy, but did not speak. Just then the fog, through an opening of which the iceberg had been seen, began to close over it, and it soon disappeared.

Lawrence then turned to Mrs. Gray again.

"Well, Mrs. Gray," said he, "it seems to be gone. Will you remain upon deck any longer, or shall I assist you to go back to the saloon?"

Mrs. Gray said it was rather damp, and she thought it would be better for her to go down. Almira said she would remain a little longer, and see whether the iceberg would come in sight again. So Lawrence, taking Mrs. Gray's glass in his hand, offered her his arm, and conducted her back to her seat in the saloon. When she had taken her seat, he sat down opposite to her. She was much gratified to see that he did not appear to be in any haste to leave her and return to the company of the young ladies on deck, and she began to talk to him about Flippy.

"I am very much obliged to you," she said, "for taking so much interest in my boy. He seems to be very fond of you."

"He is a very bright boy," said Lawrence; "I like him very much."

"He is bright enough, I suppose," said Mrs. Gray, "but he is a great bother. He is always making me trouble. He is very much interested in the instructions which you give him, though I am afraid that he does not always get things straight. There was one thing he said a day or two ago which surprised me very much. He said you told him that you could not make a fire any hotter by blowing it with the bellows. I told him I was sure it could be made a great deal hotter."

"You were entirely right, Mrs. Gray," said Lawrence. "It *can* be made a great deal hotter."

"I knew it could," said Mrs. Gray, "and with the same coal too. He said it could not be made hotter with the same coal."

Lawrence thought there might, perhaps, be some question whether it was Flippy or his mother that did not "get things straight" in this case. But he was not certain, after all, but that Flippy had stated the case wrong.

"There was some mistake somewhere," said Lawrence. "Perhaps I did not make the case quite clear, or Flippy may not have expressed himself as he ought to have done. We can't expect boys of his age to be always very accurate in expressing their ideas. At any rate, you were certainly right in thinking that a fire may be made hotter by blowing it."

After remaining some time longer and conversing with Mrs. Gray on a number of indifferent topics, Lawrence took leave of her and went upon deck, saying that he would go and see if the iceberg had come in sight again. Very soon after he went away, the lady whom Mrs. Gray called Caroline returned. As soon as she had taken her seat, Mrs. Gray said,

"I find I was entirely mistaken about Mr. Wollaston. He is one of the most perfect gentlemen I ever knew. It was all Flippy's work, in giving me a wrong idea of him. He always makes a mess of every thing he meddles with.

"Besides," she added, "he did not say any such a thing as that fire could not be made any hotter by blowing it. I knew he did not."

CHAPTER XX.

THE WORK OF THE ARCTIC ICE.

THERE is something very curious, which Lawrence explained a day or two after this to Miss Almira and to the two boys, in respect to the work which the stream of icebergs and fields of ice-floes and of broken ice performs in aiding the Gulf Stream in its work of conveying a portion of the heat of the tropics to the regions around the poles. The Gulf Stream, as has already been said, brings a current of water fifty miles wide and a thousand feet deep for a distance of a thousand miles from the Gulf of Mexico into the Northern Seas. Off the coasts of Labrador and Newfoundland this current meets a great stream of ice coming in the contrary direction, and it is singular enough that this very flow, though coming from north to south, operates most effectually in continuing the movement of the heat brought thus far by the Gulf Stream from the Gulf of Mexico to Newfoundland.

There are two or three aspects in which the operation may be viewed, which will show the truth of this.

In the first place, as cold is merely the absence of heat—that is to say, the contrary of it, the removing of cold from any place is equivalent to the introduction of heat into it. Thus the bringing out of so much ice from the arctic regions operates to diminish the cold of those regions, which is only saying, in other words, to increase the heat.

But, in the second place, by looking at the subject a little more particularly, we can see, to some extent, how this is done. The iceberg, as it moves through the water on its way from north to south, must continually displace, as it advances, a portion of water equal to the bulk of the part submerged, and this portion, or its equivalent, must move from south to north to fill the space which would otherwise be left empty. The movement of the mass of ice in one direction necessarily involves a corresponding movement of an equal mass of water in the other direction.

Thus the immense stream of ice, in meeting the warm water of the Gulf Stream at the Banks of Newfoundland, acts virtually to continue its movement toward the north, each block of ice contributing its portion of the effect by causing an equal bulk of water to exchange places with it, as it were, as it comes on. It is true that this interchange does not necessarily take place in the immediate vicinity of each particular block, but it must really take place somewhere, for the level of the sea at the north remains unchanged, proving that the vacancy which would otherwise be made by the going out of the ice is fully supplied, in some way, by the water flowing in; and the result is the same, in respect to a diminution of the cold, whether the water which replaces the ice flows in by the side of the outflow, or on the other side of the pole, or even by vapors through the air.

Now the ice, when it commences its movement, might probably have been 50° below zero; but the water which, by its coming out, is forced in, could not have been lower than 27° above, as that is the temperature at which salt water freezes.

If it were *fresh* water that was forced in to take the place of the ice, it could not be colder than 32° above, as that is the freezing point for fresh water. But the ordinary salt water of the ocean stands a greater degree of cold than that, and does not freeze till it gets down to 27°. That is one reason why lakes, and ponds, and rivers inland freeze much sooner than bays and inlets from the sea.

Thus one way is very clear in which the flow of the ice to the south has the effect of carrying heat to the north—by bringing away what is intensely cold, and causing its place to be supplied by something 80° or 90° warmer. But this difference of temperature is by no means the whole, or even the principal part of the difference between water and ice, for the water carries with it not only the heat which is employed in raising its temperature, but also that much larger portion which is required to maintain it in its liquid state—namely, *one hundred and forty units of heat to each pound*—which amount is latent, *as heat*, in the water, being in action in it *as force*, altering in some mysterious way the internal constitution of the substance of the water, so as to maintain it in a liquid state without altering its temperature—that is, without making it feel any warmer to the touch, or indicating any higher degree of heat by the thermometer.

This is a fundamental consideration—one which it is very important that any one studying the philosophy of heat should clearly understand and fix in his memory—namely, that you must extract a very large amount of heat from water, *after* you get it cold enough to *begin* to freeze, in order to effect the freezing of it. And, what is very remarkable, and very important to be understood and remembered, it is found, by the most exact and careful observations, that *precisely this amount of heat*, the taking away of which was required to allow the water to become solid, must be restored to it to make it liquid again.

And when the heat is thus restored, although it would be enough, if it were employed in raising the temperature of the water, to make it scalding hot, it does not raise the temperature at all. It becomes *latent*, as the scientific books express it, which word means hidden. It is employed in altering the constitution of the body from a solid to a liquid. But, though thus latent as heat, it is not lost. It is not even diminished. It all remains at its post, operating in the work of maintaining the water in a liquid state, after it has made it liquid, and must be again given out in full without the least abatement or diminution, or, rather, must be again taken out before the water can become solid again.

The heat which is thus absorbed by a solid body in making it liquid, and thus becomes latent—that is, imperceptible to the senses in any way—is called the *heat of fusion* or of *liquefaction*. It is considered as becoming a *force*, which is exercised, as we have already said, in maintaining the body in a liquid state. From this and similar cases has arisen the idea of considering heat as a form of force; and, as we have no distinct idea of force except as manifesting itself in some kind of motion, or tendency to motion, it is customary with some writers to represent heat as a mode of motion. All that we certainly know is that, in some secret way, when ice is thawed a great amount of heat mysteriously disappears, and in some way acts as a force to keep the water liquid; and that exactly this amount, neither less or more, must be abstracted before it can become solid again.

This is the reason why a piece of ice in a glass of water will cool it so much more than a piece of white marble would of the same size, even though the marble were just as cold. The reason is that the marble would only draw off enough heat from the water to warm itself up to the temperature of the water; whereas the ice would absorb enough not only to warm itself up to that temperature, but also enough to *liquefy* itself, which would require about ten or fifteen times as much, the exact amount depending upon the temperature of the water on which the experiment was made, and on other circumstances. In other words, a lump of ice will extract as much heat from a glass of water—that is, will cool it as much—as ten or fifteen pieces of marble of the same size and just as cold! In the same manner, the vast icebergs and fields of ice which come down from the north extract a vast amount of heat from the water in which they melt—not merely enough to warm the substance of them up to the temperature of the water, but also to *liquefy them*, which requires ten or fifteen times as much as would be required merely to warm them.

It is on a principle almost identical with this that water acts so efficiently in extinguishing fire, namely, through the enormous quantity of heat which is absorbed by it in being converted into steam. A pound of cold *sand* or *ashes* thrown upon a fire would cool it only to the extent of the quantity of heat required to raise the temperature of the sand or the ashes up to that of the burning fuel. But a pound of water thrown on has not only to be heated —that is, to have its temperature raised, which would of itself require more heat than the sand or the ashes, on account, as will hereafter be shown, of its greater capacity for heat, but also has to be *vaporized*, which requires a very large quantity of heat besides. Thus the special efficiency of water in extinguishing fires depends upon the enormous quantity of *heat of vaporization* which it absorbs from it. There are other effects produced by the water which aid in the result, but this is the principal source of the cooling and extinguishing power of the water in its action upon fire.

It is calculated that an iceberg will cool at least twice its bulk of water, from being blood-warm to the freezing point, *without warming itself* at all, but only melting itself—that is, the heat which it derives from the water around it, and which is spent in liquefying it, without raising the temperature of the substance of it at all, is so great that the loss of it will cool more than twice its bulk of water 50°.

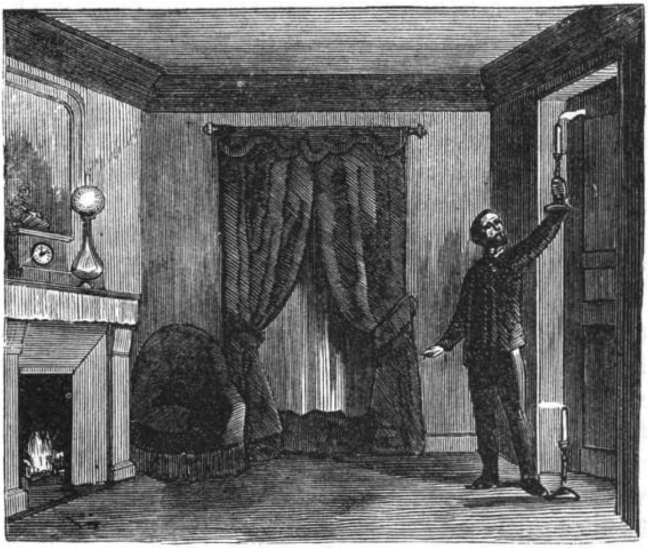
In consequence of this absorption of heat from all the water around it, a melting iceberg lies always in the middle of a vast bed of cold water, extending for a great distance from it on every side, by means of which the seamen can "feel" for the approach of one, as Lawrence expressed it, by means of the thermometer in foggy weather.

One day, when Lawrence was walking upon the deck with Miss Almira, she observed that the seamen were letting something down into the water, and then carefully examining it when they brought it up. Miss Almira asked Lawrence what they were doing. He said they were *feeling* for something, and asked her to guess what it was. She said that she should have thought it was for a shoal or for a sand-bank, were it not that the line was not long enough for a sounding-line. Lawrence said that they were *feeling for an iceberg*, or, rather, feeling to ascertain whether there was one before them on their course that they were in danger of encountering.

"Every great mass of ice in this latitude," he said, "and in a calm day, lies in the centre of a *sphere of cold*, which it has formed around it, the lower part of it consisting of water, and the upper part of air. The chill which it produces extends sometimes for a mile or two, and the existence of this chill diminishes very much the danger of the voyage by the warning that it gives. When the weather is clear, the icebergs can be *seen* at a sufficient distance; and even field-ice produces a peculiar effect upon the sky above it, which gives seasonable notice. But in fogs, and in dark and rainy nights, the increasing coldness of the air, and more especially that of the water, as the vessel comes within the brink of danger, are the only warnings.

"There is another very curious and very important principle in respect to the manner in which the ice-field and icebergs act in aiding the transfer of heat from the polar to the equatorial regions, and thus equalizing in some degree the temperature of the globe. From the mass of cold water which lies beneath and around the ice, a current is all the time flowing downward toward the bottom of the sea, and thence onward toward the south, under the warmer water which has come from the south on the surface. The effect is just the reverse of that produced by candles or lamps in a room. From a dozen of such lamps or candles burning in a cool room, streams of heated air are all the time ascending and spreading in every direction along the ceiling, over the cooler air below. When there is smoke or steam in these currents, their course is made distinctly visible.

"On the same principle, but in a contrary way, from every iceberg floating in the sea, we should see, if our eyes could penetrate to the depths below them, and if there was any change produced in the color of the water to make the currents visible, a slowly descending stream, of vast volume, flowing beneath the warmer water of the surface above. These cold descending streams, which come, in proper measure and degree, from every field, and floe, and fragment of ice, join below with the vast current of cold water flowing from the north to the south to take the place of the warm current at the surface from south to north. The existence of these two currents, and the difference of their temperature, is fully shown, by proper observations, with sounding-lines and other instruments, as clearly, though not quite so easily, as the outgoing current of warm air at the top of an open door in a warm room,



INCOMING AND OUTGOING CURRENTS.

and the incoming one of cold air at the bottom of the door, by the flame of a candle."

At one time when Lawrence was talking with the boys on these subjects in the saloon, just after tea, Flippy made some remark which implied that it seemed strange to him to talk about heat in connection with *icebergs* and *cold water*, which he thought had no heat in them at all.

"Yes," said Lawrence, "you are perfectly right. There is no heat in them, as the word heat is usually understood in common conversation; but in science and philosophy the word is used in a different way. In common conversation, a thing is hot when it feels hot to the hand; and that led to an old saying, that there is no heat in fire, which is very true, if you mean by heat the *hot feeling*, for it is plain that there can be no feeling at all in fire of any kind.

"But in science we mean by heat that force, or quality, or whatever it is, in a substance which *causes* it to feel hot to the hand—that is to say, not the feeling, but the cause of the feeling. Now it is proved very positively that there may be a great deal of that force or quality in any substance, and yet not enough to make it feel hot. Indeed, whether it feels hot or not depends on very slight and accidental circumstances. I'll show you.

"Steward," he added, speaking to one of the waiters who was just then going by, "give me a little ice, please."

The steward took from under the seat a shallow dish, filled with pieces of ice, and containing also a spoon. Lawrence then drew toward him upon the table three tumblers and a decanter of water, and filled *two* tumblers nearly full from the decanter. He put a piece of ice in one of them, and stirred it around to cool the water. He left the water in the second tumbler as it was. The third tumbler he filled partly with cold and partly with hot water, which last he took from a tea-pot containing hot water which still remained on the table, tempering the mixture so as to make it not too hot for a person to bear his hand in it.

Thus there were three glasses, one containing ice-cold water, one which was quite hot, and a third, which he placed in the middle between the other two, of a medium temperature. Then he directed Flippy to put two fingers of one hand in the cold water, and two of the other hand in the warm water, and hold them there until the fingers in one case had become quite warm, and in the other quite cold.

"Now," said he, "dip your cold fingers into the middle tumbler, and tell me how it feels."

Flippy did so, and said it felt very warm.

"And now," said Lawrence, "dip the warm fingers in."

He did so, and exclaimed,

"Ah! now it feels quite cold."

"So you see," said Lawrence, "that the feeling in our hands is no criterion even of temperature, much less of the amount of heat—the cause of temperature—which may exist in great quantities, and yet be entirely disguised."

John was very much interested in trying this experiment too, and he carried the glasses over to Miss Almira, who was sitting at the time on the other side of the saloon. She said she had seen the experiment described in books, but had never tried it before, and was very glad of the opportunity.

"So you see," said Lawrence, when John and Flippy came back with the glasses, "if there was an animal whose blood was naturally as warm as your fingers became in the warm water, the middle water would always seem cold to them; and, on the other hand, if there were animals whose blood was as cold as ice-water, and they were sensible to the feeling of heat, no water that remained unfrozen would feel cold to them in the coldest winter weather. We know that there is some heat in the coldest substances existing in nature, for, however cold they are, the chemists can by artificial means make them colder."

So Lawrence called the steward, and, pointing to the glasses which they had been experimenting with, asked him to take them away.

CHAPTER XXI.

HEAT A FORM OF FORCE.

Heat used to be considered as a very subtle and volatile *substance* which was emitted from the sun and pervaded all other substances in nature, and, when it was so considered, it was designated by the name of *caloric*. It was finally proved not to be a distinct substance, and that in a very remarkable way. It was done by boring an iron cannon under water, the water being heated by the friction. Now, if the heat had been a *substance* residing in the iron, the supply would, after a while, have become exhausted, and the boring would have ceased to heat the water. But it was found that the friction did not so cease to evolve heat; on the contrary, the heat continued to be produced as long as the boring was continued. From this and from a great many other similar experiments and observations, and after half a century of very earnest discussions, in which the whole scientific world took an active part, it has come to be universally believed that heat is a *form of force*, and the old word caloric, with the theory which it implied, has been abandoned.

If any of the readers of this book should find that they do not understand this very well—that they can not get any clear mental picture of heat as a form of force, or of heat being changed into force, or of force changed into heat, they have reason to feel encouraged, for those who have made the greatest advances in the study of this subject find continually open before them glimpses into regions of thought where they can see nothing clearly. And when they advance farther, so as to make tolerably clear what had before seemed mysterious and incomprehensible, in so doing they always bring other regions dimly into view beyond, perhaps more mysterious and incomprehensible still. There is no coming out to the end, in the study of nature, any where. The field widens and expands more and more the farther we advance.

If, therefore, you understand clearly the special points which I have endeavored to explain in this volume, and begin to see before you many others, in the contemplation of which your thoughts get bewildered and lost, you have reason to think you are all right—that is to say, that you are on the right road. There are no other roads but such as this into the vast field of science open to the exploration of man. Those who have advanced the farthest, and who understand the most, see before them the greatest area, that remains to be explored, and is yet involved in inscrutable mystery.

Lawrence had some conversation with Miss Almira on this subject one morning, after the Banks had been passed, and when the ship was steaming on through the clearer atmosphere and under the purer sky beyond. There was a pleasant breeze blowing from the southeast, but as the vessel was going toward the northwest — that is, nearly in the same direction with the wind—and as the velocity of the wind was just about the same as that of the vessel, it seemed calm upon the decks, and a great many ladies were seated upon the settees and upon their folding chairs, in the wide open part of the upper deck between the wheel-houses, where the view over the water forward was nearly uninterrupted. Some were reading, some were engaged in work, and some in conversation, and all were animated with the thought that they had passed over the most disagreeable and only dangerous part of the way, and were enjoying pleasant anticipations of a safe arrival at Liverpool after a few more days.

Lawrence provided a seat for Miss Almira at a place which commanded a good view "ahead," and had then taken a seat beside her. They had been talking for some time on various subjects not at all connected with the science of heat—about America, the scenery in different parts of the country where they both had traveled, and the different characteristics, manners, and customs of the large cities. Lawrence had a strong desire to ask Miss Almira what her other name was, and where she lived, but he was not sure that it would be quite discreet to do so, knowing well that it is a rule of polite society that persons meeting thus, as it were, by chance in public places ought not to be inquisitive about each other.

In the course of the conversation, and in alluding to their approaching arrival, Almira said that she was glad that she had met Lawrence, and that she was much indebted to him for many new ideas which he had given her on scientific subjects—ideas, she said, that had turned her thoughts in new directions, and would make her feel a greater interest in reading about such subjects than ever before. Among other things, she spoke of the thermometer as not measuring *quantity* at all in heat.

"No," said Lawrence, "it only marks *points in a line of progress.* We may infer quantities sometimes from two or more of its indications, but its indications do not directly denote quantity at all. Thus, when we say the thermometer is at 30, the 30 does not denote 30 units of heat, or 30 quantities of heat of any kind. It means simply that the mercury is at the *thirtieth mark* on a certain scale. It is an *ordinal* number in reality, not a *cardinal* one."

Almira said, in conversing farther on the subject, that she found it very difficult to obtain any clear idea of *latent* heat. "If heat is motion," she said, "what is latent motion? Indeed, I can not picture to mind a *latent force* of any kind. If two bodies are moving toward each other, I can form some conception of the persistency of their motion as a force. But if they are stopped by some other force, so that they can not go on, but only have a tendency to go on, what is that tendency? I can not picture it to my mind at all.

"In the case of coal, for example," she said, "there is a great force stored up in it—a force derived from the sun, and which, when it is released, acts with immense power. But what is a *force stored up?* I can only conceive of a force as acting. If it is not acting, it does not seem to be force."

"It is one of those cases," said Lawrence, "in which we seem to come to the confines of human knowledge—cases in which we have proof that certain things exist, and yet the mode and manner of their existence eludes our thought. We can not grasp them, and, in attempting to do so, we become bewildered and lost. There are a great many such cases. Take the ideas of space and of time, for instance. We can not picture to our minds space or time as coming to an end, nor can we picture them to our minds as being without end, for we can not conceive *infinity* in any form. So in regard to the ultimate constitution of matter. The common conception, perhaps, of most people is, that matter consists ultimately of extremely minute particles or atoms which can not be divided. But if these particles have any magnitude at all, it would seem that they must be composed of parts, and so can not be *ultimate;* and if they have no magnitude at all, it would seem that they must be nothing.

"It is somewhat so in our attempts to follow out the idea of force to its elementary nature," continued Lawrence. "It is difficult, if not impossible, for us to form any mental picture or conception of the condition of the force that is pent up, so to speak, in a mass of coal, just as it is in respect to the force held in reserve by a bow in a bow-gun."

Just at this point in the conversation, John and Flippy, who had been walking about and sometimes standing near, overheard these words, and Flippy's attention was caught by them.

"Let us stop," said he, "and hear what they are saying about a bow-gun."

"When the bow is drawn," continued Lawrence, "the force which the boy employed in drawing it, if he lets the string fly immediately, expends itself at once in driving the arrow through the air. If, on the other hand, he passes the string over the little peg made to hold it, that force would be held in reserve. It is *stored*, as it were, in some mysterious way, in the elasticity of the bow, and may be held there for any length of time without increase or diminution."

"No," said John; "for if you keep it strained too long, it will *take a set*, more or less, and will not shoot the arrow so far."

"You are right," said Lawrence. "If the bow is made of wood, or of any other substance that is not perfectly elastic, some of the force pent up will expend itself in altering the internal constitution of the wood. But if the substance is perfectly elastic, as, for example, if the force is stored in compressed air, then it may remain latent, as it were, for a long time, and when it is released, precisely the amount that was stored, neither more nor less, will come into action. We have abundant proof of *the fact*, though all our attempts to form any satisfactory mental picture or conception of force thus stored are vain. It is substantially the same with the chemical force stored in coal by the process of vegetation."

On the evening of the day when this conversation was held, John was in the saloon writing in his journal, when Almira came and sat down by him. He showed her the pictures which he had put in, and read to her what he had written about some of them. Finally he told her that he wished that she would write something in his journal, that he might have it to remember her by.

She said she would do it with pleasure.

"I will write a riddle," said she, "which will remind you of what Mr. Wollaston told us about force in reserve, so that when you see the riddle in your book you will not only be reminded of me, but also of Mr. Wollaston, and of what we have learned from him about heat and force on this voyage."

So she took the book, and the next day brought it back to John. On opening to the place, he found this riddle:

RIDDLE.

He has no wings,
And never sings,
And never speaks a word;
But he can fly
Up very high—
As high as any bird.

Underneath this riddle was a square piece of paper gummed on by the upper edge, leaving the under edge free. On the paper was written the word

ANSWER.

On lifting up the paper, John saw a picture of an arrow in the act of mounting into the air, as if just shot off under the impulse of the force which had been stored in the elasticity of the bow by drawing the string.

CHAPTER XXII.

THE MECHANICAL EQUIVALENT OF HEAT.

THAT heat is a form of force, or that heat and force have something in their nature that is common, is shown to the satisfaction of scientific men from the fact that force may be derived from heat, and that just to the extent that force is derived from it the heat disappears.

In the same manner, also, heat may be produced by the expenditure of force, and just in proportion to the force expended is the heat that is produced.

The unit of heat used for measuring, or, rather, for affording *means of expressing* quantities of heat, is, as has already been stated, the quantity which will raise the temperature of one pound of water one degree of the English thermometer.

The unit of *force* which is used as a means of denoting or expressing quantities of force is the amount expended in raising a weight of one pound one foot in height at the surface of the earth. It is called a *foot-pound.*

Now, when heat and force were found to be mutually convertible into each other, it became at once a very curious question what was the numerical ratio between them; in other words, how much force any given quantity of heat is capable of producing, and the converse.

A great number of investigations and experiments, by many different philosophers, have been made for the purpose of determining this point. It has at length been ascertained to the full satisfaction of the whole scientific world, and it is called *the mechanical equivalent of heat.*

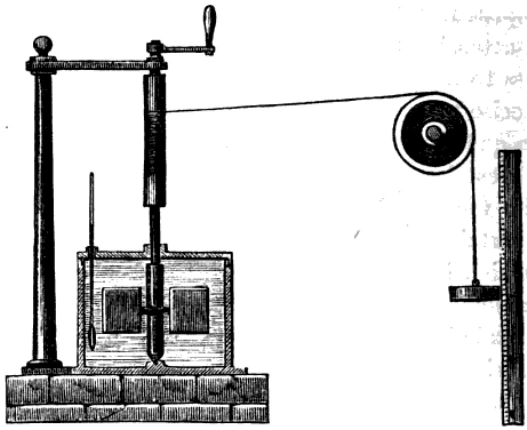
I suppose that those of my readers who have never paid special attention to such subjects as these would be quite at a loss to imagine by what kind of contrivance any certain precise amount of force could be converted into heat, and the quantity of heat so produced be exactly measured, so as to establish the ratio of one to the other. The person who took the most active part in this investigation was a certain English engineer named Joule. The equivalent which he ascertained by his experiments has since been abundantly confirmed by numerous other experiments made in a great variety of ways, and is now universally received as the English expression of the equivalence of force and heat, and is known as Joule's Experiment. It is this; and every person interested in such studies as these ought to fix it firmly in his memory:

A unit of heat is equivalent to seven hundred and seventy-two foot-pounds.

That is to say, the heat required to raise 1 pound of water through 1 degree of temperature of Fahrenheit's thermometer may be made to act as a force to the extent of raising 772 pounds weight 1 foot high, or 1 pound 772 feet high, or 386 pounds 2 feet high, or to do any other equivalent amount of lifting.

On the other hand, a weight of 772 pounds falling 1 foot, or 1 pound falling 772 feet, or any other equivalent amount of force exercised by a body in falling, when arrested, develops sufficient heat to raise 1 pound of water 1 degree of Fahrenheit's thermometer.

The general principle on which Joule's method of ascertaining this equivalent is founded will be easily understood by the following engraving. On the right you see an iron weight, which descends along a scale marked in feet and inches. The cord from this weight passes over a pulley above, and thence is carried to the left, where it is wound



JOULE'S APPARATUS.

many times around a vertical axle. The upper part of this axle has a winch, by means of which the axle may be wound up, and the weight set at any point on the scale.

The lower part of the axle passes down into a vessel of water, and has vanes attached to it, which, by the revolution of the axle, are made to agitate the water and produce friction among the particles. You would not suppose that the friction, or any other effect produced among the particles of water, would evolve heat, but it does so, and that in exact proportion to the amount of force expended in producing the friction. A thermometer, which you see projecting its tube above the vessel of water on the left, shows, when the experiment is made with this apparatus, just how much the temperature of the water has been raised by the descent of the weight through any given space. And from these elements—the weight of the descending iron and that of the water also being known—it is easy to calculate how many units of heat have been transferred to the water by the descending force of the iron.

The engraving only shows the general principle of the method. In the actual experiments made by Joule, a great many contrivances were necessary to guard against or allow for sources of error which would otherwise have affected the result, such as the escape of heat through the walls of the vessel, and the waste of force in the friction of the pulley. These details we have not space to explain, nor is it necessary to attempt it, as it is only the general principle which we wish here to show.

The great thing is to remember the result, which is a principle of fundamental importance in the science of heat and force, namely:

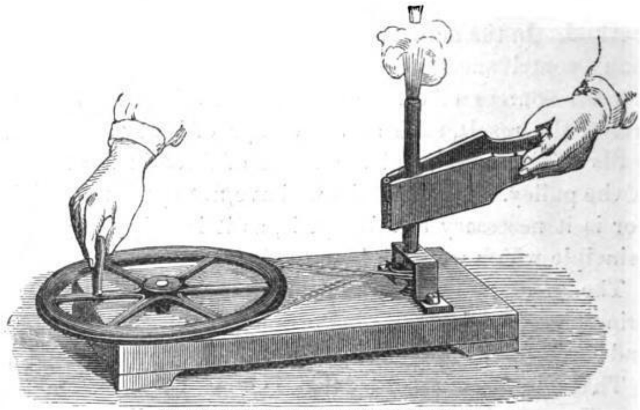
That the force equal to that exercised by 1 pound descending 772 feet is equivalent to a quantity of heat sufficient to raise the temperature of 1 pound of water 1 English degree. In other words, that

1 unit of heat is equivalent to 772 foot-pounds of force.

There are a great many ways by which the conversion of force into heat, and the evolution of heat by the expenditure of force, is exemplified in natural phenomena occurring around us, or may be made manifest by artificial contrivances. One of the most curious and striking of these last is shown in the engraving on the following page.

The tube on the left, which is held between the arms of a wooden grip, as shown, is an iron one, and is half filled, at the commencement of the experiment, with water. On turning the wheel the tube is made to revolve, and the heat produced by the friction soon becomes so great as to boil the water, and thus soon to force out the cork with an explosion, by the expansive force of the steam.

Here the muscular force of the person turning the wheel is conveyed by the mechanism to the tube, and there, between the tube and the two arms of wood clasping it, it is expended in friction, and so transformed into heat. The

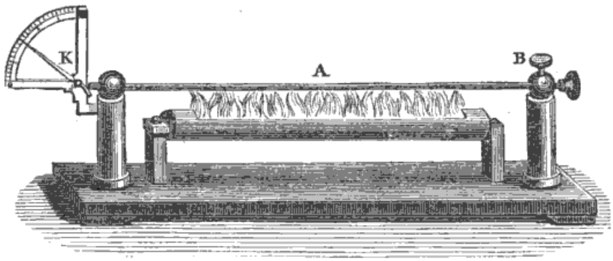


HEAT DERIVED FROM FORCE OF FRICTION.

heat is converted into force, which it expends in altering the internal constitution of the water by converting it into steam, and this force expends itself, or a portion of itself, in projecting the cork into the air, as you see.

This is an example of the conversion of force into heat, namely, force expended in friction. Instances innumerable are occurring all around us of heat acting as a force—that is, being converted into force. Heat acts as a force in expanding a vast variety of substances. It expands air, and all gaseous substances. It expands iron, and all metals. The expansion of a metal like iron is shown by heating a bar or rod, and it is found by accurate measurement that its length increases. An experiment often made at public lectures to make the expansion of iron by heat perceptible to the eye is shown in the following engraving.

A long lamp, with a line of wicks, is made to burn under an iron bar, A, which is held firmly by a binding screw at one end, B, and passes through an opening in the upright standard at the other end, through which it is free to move. As it expands by the heat, the outer end presses

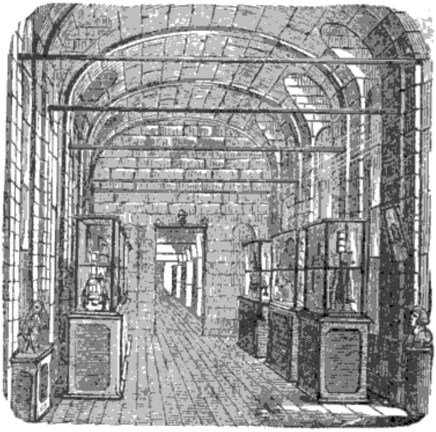


HEAT CONVERTED INTO EXPANSIVE FORCE.

against the short or lower end of the index, which, acting as a lever, moves the upper end a very considerable distance over the graded arc K, which makes the progress of expansion, as the iron becomes more and more heated, very perceptible.

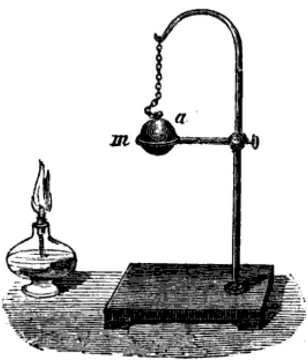
The expansion of iron, though it seems very slight when measured by the amount of increase in the length of the bar, is really the expression of a prodigious force, as is shown when the iron bar is immovably confined at one end, and is large and thick enough not to be bent to one side by the expansion, in which case it is found that it requires an enormous force to resist the advance of the free end of the bar.

There is another way of showing the vast force brought into action by this expansion, and that is by the force with which the iron contracts again when it is allowed to cool. Heavy walls of masonry, that had leaned over out of the perpendicular, have been brought back into place again by means of iron rods passing through them, and screwed by nuts on the outside. By heating these rods they would become lengthened, and would protrude farther through the opening. The nuts would then be screwed up so as to prevent the outer ends of the rods from being drawn back again through the wall. Then the rods would be allowed to cool, and the force which they would exert in springing back to their former length was found sufficient to draw in the whole wall, massive and heavy as it was. This method was employed successfully some years since in bringing back into place the walls of a large public building in Paris.



WALLS BROUGHT UP.

Now the force with which the rods, in such a case, shrink in cooling, is exactly that which the force developed by the heat has to overcome in expanding them.



THE HEATED BALL.

The effect of heat in expanding iron is sometimes shown in another way by means of an iron ball, hung from a support by a chain, and a ring placed horizontally beneath it, the two being so adjusted to each other that the ball will slip easily through the ring when it is cold. By taking the ball off from the ring, and letting it hang over the flame of a spirit lamp, it may be heated, when, on placing it upon the ring, it will be found that the ball has become too large to pass through.

Blacksmiths cause the iron band which encircles a carriage-wheel—called the tire—to grip the wheel and to hold the parts together with prodigious force, by heating it first in a circular fire, and then putting it on while it is still hot. In cooling and shrinking again, the enormous force which the heat overcame in expanding the iron comes into action, and it exerts sometimes so much power as actually to bend the spokes of the wheel.

Heat expands in this manner almost all substances, gases, vapors, metals, rocks, water, and liquids of every kind. The power of the steam-engine is all derived from the expansive force produced by the heat entering the steam after it is formed in the boiler, and there acting as a force of expansion.

In some cases the expansive effect produced by heat is not apparent, but it is not the less real on that account, as, for example, in the case of wood. The woody fibre itself, and the air filling the pores, are expanded; but, the substance being porous, the increase of bulk is taken up, so to speak, *in the pores*, so that the external dimensions of the mass are not sensibly changed.

This tendency of iron to expand and contract with the changes in its condition in respect to heat and cold has to be taken into account in a great many operations. For example, if you look at the iron rails on a railroad in the winter, or in any cool weather, you will see that the ends do not quite touch each other. There is a little space left between each pair to allow for the expansion. If the rails were laid so that they would touch in the winter, they would expand so much in the hot days of summer that they would bulge each other out of line; and so great is the force by which this expansion would be effected, that there would be no practicable way of fixing the rails in their places so as to prevent their being thus deranged.

The most solid rocks shrink and swell in this manner as they are alternately heated and cooled. Several years since some scientific men connected with Harvard College wished to perform some experiments which required the use of an extremely long pendulum, and they concluded to make use of the Bunker Hill Monument for the suspension of it. The first thing was to hang the pendulum, and then to bring it to a state of perfect rest, with a point from the lower part of it directly over a certain point marked on the floor. But they found that they could not bring this point to a state of permanent rest over the same point on the floor, and, after quite a long series of observations and examinations, they found that the whole monument was bent this way and that alternately, every day, by the swelling of the sides of the structure as the sun shone upon them in succession, thus continually shifting the point of suspension. In the morning, when the sun shone on the eastern side, the monument was bent over toward the west —but very little, it is true, but still to a sensible degree. In the middle of the day, when the sun shone on the south side, the monument was bent toward the north, and in the afternoon toward the east. The effect was found, as might have been expected, to be most marked and striking on hot days, when the sun shone bright and clear.

The rocks which form the strata lying near the surface of the earth, where they are near enough to come under the direct influence of the sun, must expand and contract thus every twenty-four hours, as they are warmed by the sun during the day, and allowed to cool again at night;

and the same effect must be produced on a still larger scale from the changes of temperature produced by the different seasons of the year. The innumerable rents, and fissures, and crevices which we see every where in ledges of rocks lying near the surface of the ground are due, doubtless, in a large measure, to the alternate expansions and contractions arising from this cause.

It is found that not only do almost all substances thus expand by heat, but they expand very regularly—that is, that within certain very wide limits equal additions of heat at all temperatures produce equal degrees of expansion.

But I shall have something more to say in relation to this subject in the next chapter

CHAPTER XXIII.

THERMOMETERS.

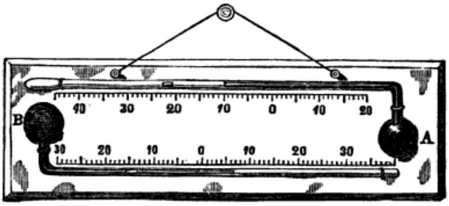
It is in consequence of the law referred to at the close of the last chapter—namely, that equal additions of heat under ordinary circumstances produce in most substances equal degrees of expansion—that the state of expansion or contraction of any substance may be made use of as a measurement of temperature. An iron bar like the one shown in the engraving as heated by flame would make *in principle* a good thermometer, for the needle would show by its position the temperature of the surrounding air, the point of it moving a great way with a very slight change in the length of the bar. But it would make a very inconvenient one in practice.

It is found much better to use some liquid substance, for a considerable quantity of such a substance can be inclosed in a bulb, with a tube of fine bore attached to it, and thus a small expansion of the whole mass in the bulb, by forcing a slender thread of its substance up the tube, will produce a great visible effect. Water will not answer very well; for, besides some other objections to it, it would freeze when the weather was even moderately cold.

Mercury answers the purpose admirably well, but even mercury freezes at 39° below zero, and it is often desirable to measure temperatures lower than that. The temperature in the Arctic regions falls sometimes to 60° below zero, and even lower, and in such a case a mercurial thermometer would be of no use.

Alcohol is much better than mercury in this respect, namely, that it will measure very much lower temperatures than mercury without freezing. When alcohol is employed, it is usually colored red, so as to make it more plainly visible in the tube.

There is a kind of thermometer called the self-registering thermometer. It consists really of two thermometers, one for the greatest heat and one for the greatest cold, both placed in the same frame.



SELF-REGISTERING THERMOMETER.

The engraving gives a representation of one of these compound instruments. The upper part of the instrument contains a tube joined to a bulb filled with mercury (A), and also a little button of glass or porcelain, which you see in the tube just over the figure 20. When the air grows warmer, it causes the mercury to expand, and as it swells in the bulb, and as the column of it advances in the tube, it pushes this little button before it; and then, when it contracts again, as the weather grows cooler, it leaves it at the farthest point which it has reached; so that, when you come afterward to look at your thermometer, you can not only see what the temperature is at the time of your visit, but can also see how hot it has been during the day.

Below is an alcohol thermometer (B), with a somewhat similar button, only this lies *in* the alcohol instead of being before it, as the one in the upper tube was in relation to the mercury. When the weather grows cold, and the alcohol shrinks and draws back toward the bulb, it pulls the button back with it as far as it goes, and leaves it there when it grows warmer and the alcohol moves forward again. Accordingly, when you come to look at this part of the thermometer in the morning, after a cold night, you can not only see how cold it is when you look, but can also see by the place of the button how cold it was at the coldest time during the night.

All that is necessary to set the instrument for a new observation is to turn it up endwise for a moment, with the end marked B uppermost, when the two buttons slide down at once to their places, ready to begin to move again at the commencement of any new change of temperature. It is a very curious instrument, and any boy who has access to one will watch its indications with great interest, especially in mornings in winter after very cold nights.

There is something important to be learned about the *zero*, so called, of the thermometer, which is the point at which the reckoning of the scale begins. In the English thermometer the zero point was fixed by what was then supposed to be the greatest possible cold, which was that produced by certain chemical mixtures, and also that of the coldest climates then known, such as Lapland. But when it was found that that was not the greatest cold, some French philosopher thought it would be better to begin the scale at the freezing point of water, and to divide the scale from that to the boiling point into 100 degrees, and they called the thermometer so made the *Centigrade.*

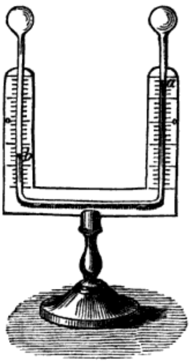
The Centigrade plan is now admitted to be much better than that of Fahrenheit, but the latter is so universally in use in English-speaking countries that it would be very difficult to change it.

Several other plans besides these two have been proposed, and have been partially adopted. Some very nice and elaborate experiments and calculations have moreover been made to determine what is called the absolute zero; that is, the point of absolute destitution of heat, which is the point where the scale should philosophically begin. It is now supposed to have been satisfactorily ascertained that this point corresponds with about 461° below the zero of Fahrenheit.

The greatest natural cold of the Arctic regions is from 60° to 80° below Fahrenheit's zero.

There is a very curious little instrument, which shows, not the absolute temperature of any one portion of the atmosphere or of any other substance, but the *difference between two such portions* near to each other. It is called, on this account, the differential thermometer. The form of this instrument is shown in the engraving below.

It consists of a glass tube bent in the form of the letter U, except that the corners are more nearly square. There is a graduated scale adapted to each of the two arms. The lower part of the tube is filled with colored alcohol, which, if the instrument is properly adjusted—that is, if it contains an equal quantity of air in each of the bulbs—will, in an equable atmosphere, stand out at the same height on each side.



DIFFERENTIAL THERMOMETER.

But if now a warm hand is brought up and made to clasp one of the bulbs, the air within that bulb is warmed and expanded, and the alcohol in that bulb is consequently pressed down and forced to rise in the other bulb, as shown by the letters *b* and *a*. Thus the difference in the elevation of the alcohol in the two arms shows the difference in the temperature of the air in the two bulbs. This instrument is very sensitive, so much so that a warm hand held in the air with the palm presented toward one bulb, but on the side opposite to the other, will cause a decided difference in the level of the alcohol in the two arms.

There is another instrument far more delicate than this for indicating slight changes of temperature, which I shall have occasion to refer to in the next chapter.

Lawrence described all these different contrivances to John and Flippy one day, and at the close of the conversation he told them that there was one kind of thermometer which a boy could make for himself, although he admitted that it would not be good for much when it was made. The boys were both very curious to know about this.

"It is called an air thermometer," said Lawrence, "because the effect is produced by the expansion of air.

"All you want," he added, "to make it is a phial—the shorter and larger round it is the better—a cork, and a slender glass tube about as large as a pipe-stem, which you can get at almost any glass store for a few cents. You bore a hole in your cork, or, what is better, burn it with a hot wire, and put in the glass tube. You fill the phial about one third full of water; then you put the cork into the mouth of it, and push the tube down through the cork until it almost, but not quite, touches the bottom; then you cement over the top of the cork with sealing-wax, or shoemaker's wax, or something of the kind, and your thermometer is done—except that you had better contrive some way to pour a little water into your tube from above, in order to bring the level of it up above the cork, where you can see it, before you set your instrument at work.

"The way it works is this," continued Lawrence: "When the weather is warm, the warmth will expand the air in the upper part of the phial, and make it press harder on the surface of the water, and so force more of it up into the tube. On the other hand, when the weather becomes cooler, the water in the tube will fall."

"But how could we tell how many degrees?" asked Flippy.

"Oh, if you want degrees to your thermometer," said Lawrence, "you must have a card, and mark degrees upon it, and fasten it up in some way upon the cork, behind the tube."

"But how can we tell how to mark the degrees so as to have them correspond to the degrees of a real thermometer?" asked John.

"Ah! that would be very difficult," said Lawrence. "I don't think you could do that very well. Besides, there are other very serious objections to such a thermometer. In very cold weather the water would freeze; then, as the top of the tube would be open, the water would be all the time slowly evaporating from it. Some vapor, too, would probably escape through the cork, no matter how tight you tried to make it. I told you the thermometer would not be of much use. You would only have the fun of making it, and seeing the water rise and fall in the tube as the weather changed, or as you held it nearer to or farther from the fire."

"I mean to make one as soon as I get home," said Flippy, "just for the fun of it; I don't care much about the use."

CHAPTER XXIV.

FORCE CONVERTED INTO HEAT.

There were some things in relation to heat that Lawrence did not attempt to explain to Flippy, nor even to John, inasmuch as the right apprehension of them involved a niceness of thought and discrimination, and a power of abstraction and generalization to which their minds had not yet become sufficiently formed. He had many conversations with Miss Almira when neither of the boys were present, as he did also with many other young ladies, and other persons of both sexes and all ages on board. Nor must it be supposed that when he was in the company of Almira he talked exclusively, or even generally, on scientific topics. He talked with her and with all his other acquaintances on a great variety of subjects, and very seldom, in fact, on those of scientific character. But it is only the conversations which related to these subjects, and especially to the subject of heat, that are recorded in this volume.

One of the points which he particularly explained to Almira and John, and which he did not attempt to explain to Flippy, was that, whenever heat in any way acted as a force, it disappeared as heat. For instance, in the melting of ice, all that portion of the 140 degrees of heat which are employed in melting it disappear as heat entirely, being converted into the mysterious force necessary to hold the water in a state of liquefaction. If you put a mass of broken ice and snow over a hot fire in a kettle, and as soon as it begins to melt try it with a thermometer, you will find it at 32°. Now this ice may take several hours in melting, during which time a great quantity of heat will pass up through the bottom of the kettle, namely, as many times 140 units of heat as there are pounds of ice and snow; but the contents of the kettle will not be warmed at all by all this accession of heat. If you put a thermometer in again at the moment when the snow and ice are all melted, you will find it still at 32°. That enormous quantity of heat has disappeared *as heat*, and now exists as *liquefying force*. It remains there, however, still; and it must all be taken out of the water, being reconverted into heat as it comes out again, before the water can be frozen, or, rather, while it is in the act of being frozen.

There is a very striking way of showing that heat, when employed in the work of liquefaction, disappears as heat, by an experiment which Lawrence performed one evening just after tea, to show the operation of the principle to Almira and John, and also to some other persons who were there at the time. He put some pieces of broken ice in a tumbler, sufficient, as he estimated, to fill it about one third full if it had been in a solid piece. Then he mixed some hot and cold water in another tumbler, pouring in first a little cold and then a little hot, and trying the temperature with a small pocket thermometer which he had, until he had made a mixture sufficient to fill the second tumbler a third full with water at about 170°. Water at 170° is quite hot; at 212° it is boiling hot.

He tried his thermometer in the ice, and found it was at 32°.

He then poured the warm water into the ice, and began stirring it with a spoon. The ice, of course, began immediately to be melted by the hot water.

"Now," said Lawrence, "the water being so hot, and the ice at 32°, one would suppose that the mixture, after the ice is melted, would be somewhere between the two. But, as the water is only 140° above the ice, which is at the rate of 140 units of heat to the pound, it will only furnish just heat enough to liquefy the ice, without warming it at all; and if the experiment had been performed with precision —that is, if the proportions had been exactly right, and if I could have adopted any means to prevent the operation from being affected by the air of the room—the mixture, after all the ice was melted, would not be any warmer than the ice itself was before, notwithstanding all the hot water which had been added to it."

Lawrence then tried his thermometer in the mixture as soon as all the ice had disappeared, and found, as he had said, that the mixture was still as nearly as possible at 32°.

Such an experiment as this shows, in a very striking manner, that the heat which is employed in melting ice disappears entirely as heat, and assumes the character of *force of liquefaction.*

It is the same when water is boiled and steam is made, only a much greater quantity of heat is required for vaporization than for liquefaction. But all that which is so employed disappears as heat entirely. It requires about 1000 units of heat for every pound. This is considerably more than enough to make the water *red hot*, if it could be employed in the work of making it hot. But it does not heat it—that is, it does not raise the temperature at all. The water was 212° when it began to boil, and, after a thousand units of heat have been poured into it from the fire, the steam resulting is just at 212°, as the water was before.

Thus all the heat produced by the combustion of the coal in the immense furnaces of the steamer disappears entirely as *heat, so far as it is expended in making steam*, and then a still farther proportion of it disappears as heat in being employed to *increase the tension of the steam* and drive the engines. If the heat so converted into force were to continue as *heat* in the ship, it would become entirely unmanageable.

In view of these truths, consider what an enormous quantity of heat is stored in the liquefying force of the water of the sea, all of which would have to be withdrawn in some way before the sea could be frozen. This is one of the reasons why the water in the sea and in great rivers makes such slow progress in becoming frozen, even in the coldest weather.

In a subsequent conversation with Almira, Lawrence explained that the *converse* of the above principle was true —namely, that as, when heat is made to develop moving force, it ceases to exist as heat, so, when moving force, or mechanical force, as it is sometimes called, is extinguished, a precisely equivalent amount of heat *reappears.*

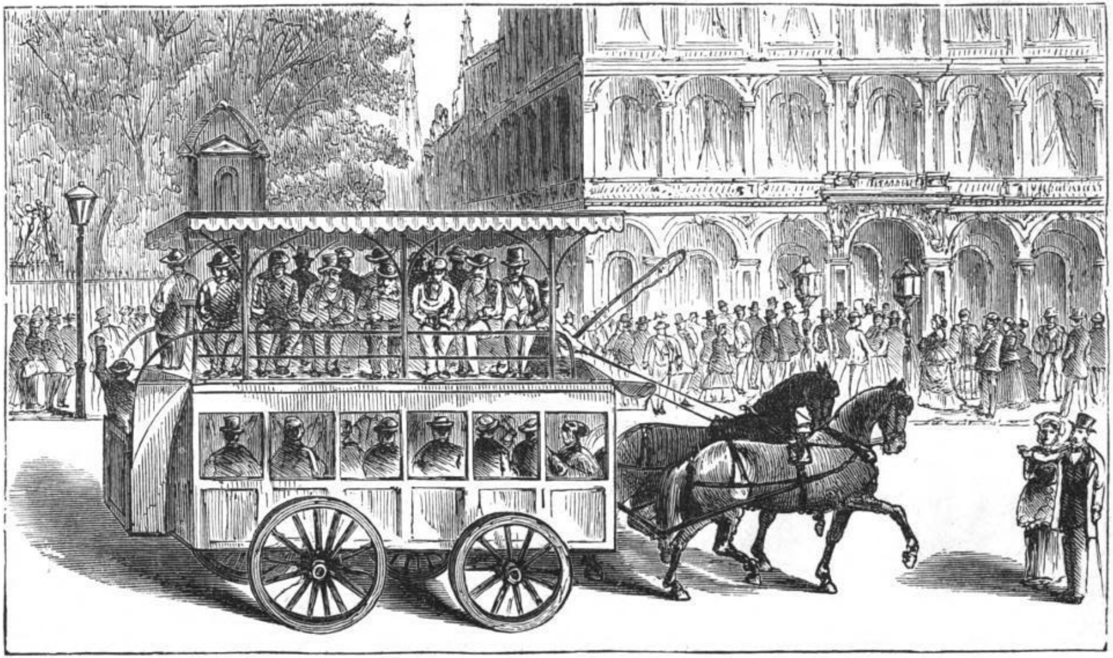
"If a bullet is fired from a musket against a solid wall," he said, "the heat which is developed by the extinction of the motion would be sufficient, it is calculated, to melt the bullet, if it could all be concentrated in the bullet instead of being divided between the bullet and the wall."

"Then I should think," said Almira, "that a cannon ball, when it strikes, would give out a very intense heat."

"It does so," said Lawrence. "It produces a vivid flash of light when it strikes a wall of masonry, or the iron-clad side of a ship, in a dark night. It is the same in all cases of the extinguishment of motion, or of the partial extinguishment of it, as, for example, in friction. When one strikes a flint and steel together, a part of the force of the stroke is extinguished by the friction, and that portion is converted into heat, and the heat thus developed is sufficient to ignite the small shaving of steel which is cut off by the sharp edge of the flint. So in all cases. If you rub your finger gently upon a table, just so far as the force you use is *extinguished* by the friction, so far a precisely equivalent amount of heat is developed. The rubbing of sleigh-runners on the pavements in a city, or on the ground in a country road, when the snow is so thin that the runners can cut through to the pavement or to the ground, makes the snow along the roadway melt much faster than it does at the sides. The result is, no doubt, affected by the operation of another cause, but the friction and the blows of the horses' feet have a great effect in developing the heat which melts the snow. The muscular force of the horses is converted into heat along the road by the *arrest and extinguishment of motion* in the friction and percussion.

"When a runner moves over solid or continuous ice or snow, the friction is very small, and then the force of the horses is no longer expended in warming the gravel and the ground, and so takes effect to a greater extent in drawing the load. The same result is attained through contrivances to diminish the friction by other means. In Paris the roadway in the streets is so smooth—often, where they are formed of asphalt, as smooth and hard as a floor—and the mechanism of the wheels is so perfect, and is kept in such perfect condition, that the omnibuses are made two stories high, and two horses are able to draw, including conductor and driver, a load of thirty persons at a rapid trot.

"It is very interesting to observe, too," continued Lawrence, "that the same phenomena of the conversion of force into heat is observed in the case of liquids. All motion of water is attended with friction, and, so far as the motion is extinguished by this cause, heat appears in its place. A river warms the sands on its banks just in proportion as its motion is aroused or impeded by its friction against them in its flow."



EFFECT OF DIMINISHED FRICTION.

"And the sea?" suggested Almira.

"It must be the same with the sea," said Lawrence. "Joule, in his celebrated experiments for determining the mechanical equivalents of heat, showed very clearly not only that the agitation of water produced heat, but measured very exactly the amount of heat produced. And so the waves of the sea, so far as the force with which they move is arrested, or retarded, or extinguished in any way by the friction of the water upon itself, or by the beat of the billows on the rocks upon the shore, must have, on the whole, a vast effect in raising the temperature of the whole mass.

"The fall of water in a cataract must develop a large

THE WATERFALL (NEVADA FALL).

quantity of heat. The precise amount might be calculated by knowing the quantity of water that falls in a given time, and the height. The heat thus produced by the extinguishment of motion has an effect in producing the mists and fogs which rise from below.

"It is so in all cases of friction or arrested motion in water," added Lawrence.

"And when we stir water with a spoon in a cup?" said Almira.

"We warm it," said Lawrence, "so far as we produce friction and consequent extinguishment of moving force among the particles."

"*My* tea always grows colder when I stir it," said Flippy, who happened to be listening to this part of the conversation.

"True," said Lawrence, "but that is because the tea, when it is hotter than the air around it, loses heat in other ways faster than it gains it from the friction. The very stirring itself makes it cool faster by bringing fresh portions to the surface in contact with the cool air. It is only so far as moving force among the particles of tea is extinguished by the friction that any heat is developed, and this is very small—very small indeed, but it is none the less real.

"So it is," continued Lawrence, "with all the motions which take place in any way in the world around us. So far as any such motion is extinguished, it is converted into heat."

"A flake of snow, for example," said Almira, "falling through the air gently and alighting upon the snow which fell before it."

"Yes," rejoined Lawrence, "that is an excellent example. So far as the flake in falling puts particles of the air in motion on its way, its moving force is not extinguished, but only *transferred*, and no heat is produced. But so far as there is any *friction* between it and the particles of air, if there is any such, so far its moving force is undoubtedly converted into heat. So that, in fact, if there is such friction, the flake warms the track through the air through which it falls, and when it strikes the ground it warms slightly the spot where it falls.

"Of course, I mean by the word *warms*," added Lawrence, "that it makes it *less cold.* The effect is infinitesimally small—wholly inappreciable by any test that we can apply, and of no use to be taken into account in any way except as a means of enabling us to receive a just and full comprehension of the universality of the law of correlation between heat and mechanical force."

CHAPTER XXV.

THE THERMO-ELECTRIC MULTIPLIER.

Although it would not be possible to measure or even to find sensible evidences of the heat developed by the fall of a snow-flake on the snow that fell before it, there is a method which has been discovered, and is in use among scientific men, for measuring astonishingly minute changes of temperature—as small, in fact, as one or two thousandth part of a degree of the Fahrenheit thermometer! The very delicate instrument by which it is effected is called Melloni's Thermo-electric Multiplier.

In the common thermometer the changes in temperature are made manifest by the power of heat to expand substances—that is, to increase their bulk. In this instrument the effect depends upon the power to set in motion, under certain circumstances, a *current of electricity*. It is found that if two metals—bismuth and antimony are the most effective for the purpose—are joined together, and the junction is *warmed*, a feeble current of electricity is set in motion from one to another; and if several pairs are made, and the heat is applied to the junctions on one side, the force of the several currents is accumulated. The engraving, Fig. 1, on the opposite page, shows the principle of the arrangement, where the bars A are the bars of antimony, and the bars B those of bismuth, the arrow showing the direction of the electric current.

Many pairs of these bars are formed, and the whole packed together in a compact manner in a case, as shown in Fig. 2. The two wires at the top are connected, the one

Fig. 1.

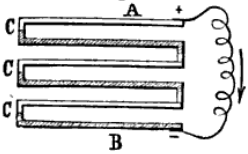


Fig. 2.

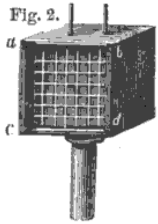
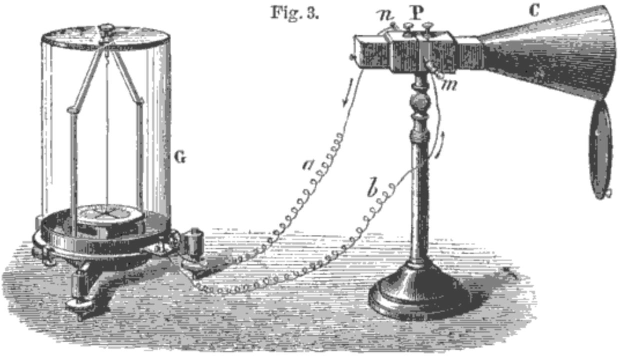


Fig. 3.



MELLONI'S THERMO-ELECTRIC MULTIPLIER.

with the bismuth and the other with the antimony end of the system, and it is through a wire joining these that the current of electricity is to flow when the apparatus is in use.

In Fig. 3, one of the instruments is shown as arranged for use. The case formed, as above, of bars of metal (P), is mounted on the stand. The two wires in this instrument, represented as coming out at the side, are connected respectively with the two electric poles of the system. The arrows show the course which the electricity is supposed to take through the wires *ab*, the ends of which are held firmly in contact with the poles of the instrument by the binding screws at P. The middle part of the wire is carried into the lower part of the instrument (G), where it is wound many times round a little frame, so as to form a flat coil, by which the effect of the current is multiplied many times, and is made to deflect a fine needle in proportion to the increase of temperature produced at the junctions of the metals in the case at P. C is a metallic cone, with the inside surface blackened, to regulate the quantity of radiated heat allowed to reach and act upon the instrument.

This general description will give a sufficient idea of the principle on which the instrument operates, which is all that is necessary for our present purpose.

With this instrument a great number and variety of experiments have been made, and a great many truths discovered, which have vastly extended the knowledge we possess of the action of heat in the general economy of nature, inasmuch as extremely minute changes of temperature can be made perceptible, and even be measured by it.

One very curious and important service performed by means of it was to determine, by another method, the mechanical equivalent of heat, which Joule had already obtained by means of the friction of water. By this new method a small stream of mercury was allowed to fall from a known height into a jar of mercury on the floor below. From the quantity of mercury which fell, and the height through which it descended, the quantity of force expended or extinguished in the jar was known, and by this instrument, the thermo-electric multiplier, the exact amount of the increase of temperature of the mercury in the jar was ascertained.

The same point has also been determined by experiments made on a great scale in a large machine-shop at a place called Hogelbach, on the Rhine, in Germany, by Mr. Hirn, one of the partners in the firm. He used a steam engine of 100-horse power for his experiments, and performed them with the greatest care and attention, and at no small expense. He succeeded in confirming, by experiments on this great scale, the results which had been previously obtained from the action of small quantities of heat. He showed, first, that in working his engine, a considerable portion of the heat which was produced by the combustion of the coal entirely disappeared; and, secondly, that the amount of mechanical motion produced by the engine—that is, of work done by it—corresponded exactly to the amount of heat which had disappeared, in the precise proportion which had been ascertained by Joule and other experimenters—namely, for English measurements, one unit of heat to 772 foot-pounds of work.

I will repeat my recommendation that every reader of this book should fix the principle, and the numerical statement of it, as above, firmly in his mind, inasmuch as this principle—that heat can be changed into mechanical force, and mechanical force into heat, at a certain fixed and determined rate, is regarded as one of the greatest discoveries of modern times.

One day, as the ship in which Lawrence and his friends were making their passage was approaching the land, the weather was so cold and chilly upon deck that a large number of the passengers had gone below. Some, however, remained in sheltering nooks and corners, and Lawrence, in passing along, observed Almira seated in a folding chair under the lee of one of the great chimneys. She was engaged in reading. Lawrence stopped to bid her good-morning as he passed, and she at once closed her book and looked up to him with a pleased expression of countenance, which led him to imagine that perhaps she would like to have him remain and keep her company. If she had kept her book open in her lap in responding to his salutation, he would have inferred that she intended, and so, probably, that she wished, to go on with her reading.

He accordingly brought up another folding chair and sat down by the side of her. They talked together for some time about various subjects, and especially about Switzerland, where Almira had never been, but where she was now going; and she was much interested in hearing the explanations which Lawrence gave her in respect to the torrents, the glaciers, and the avalanches to be seen among the Alps, which explanations would enable her much better to understand and appreciate these and the other grand phenomena of the region when she should come to see them. He gave her, moreover, an account of expeditions which he had made, in company with some other travelers and a party of guides, among the higher Alps.

I should be very glad to report some of this conversation, but mountains and glaciers are not the subject of this volume.

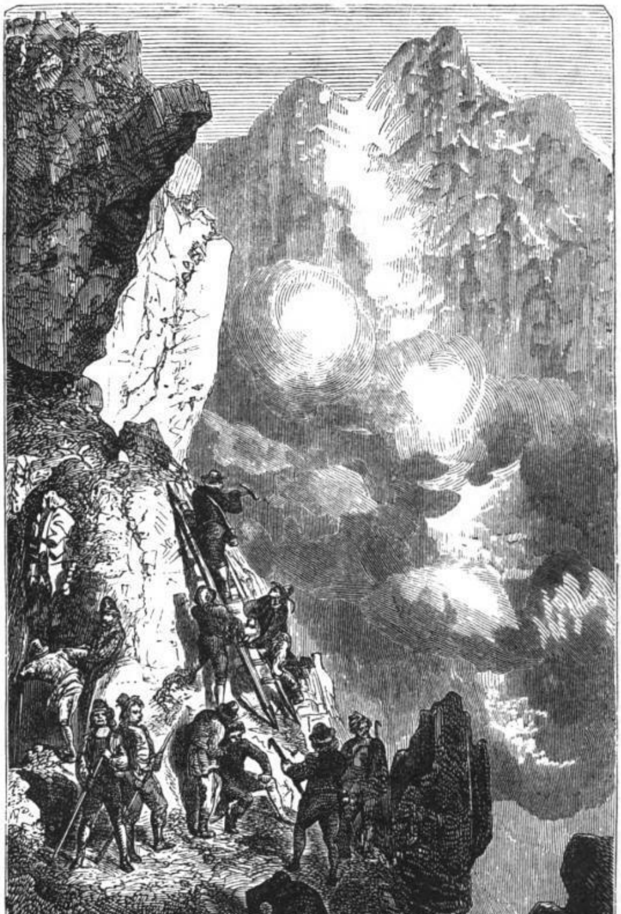
At length John and Flippy came by.

"Ah!" said Flippy, "here is a good warm place." So saying, he held out his hands toward the great chimney to warm them. The radiation from the chimney was very powerful, like that from a gigantic stove.

"Let's get some camp-stools and sit down here," said Flippy.

"Do," said Almira; "it is a very nice place, and then Mr. Lawrence will give us some more talk about heat."

"Yes," said Lawrence; "I'll make believe that you are an audience, and I will give you a regular lecture."



ADVENTURES AMONG THE ALPS.

CHAPTER XXVI.

TRANSMISSION OF HEAT.

So the boys brought camp-stools, and established themselves comfortably under the shelter of the chimney and in its warmth, and then, after some few minutes spent in common playful conversation, Lawrence began.

"Ladies and gentlemen,—This is to be a lecture of hard words."

"You can't say *ladies* to your audience," interrupted Flippy, "for there is only one."

"I am making believe that it is a large audience," said Lawrence.

"Go ahead," said Flippy.

"The hard words," continued Lawrence, speaking in a deliberate and oratorical tone, as if he were a lecturer addressing an assembly, "relate, all but one, to the *movement* of heat. They are these:

"Radiation, Reflection, Refraction, Conduction, Convection, and Attention.

"I shall explain what these words mean, and if any of my audience forget any of them, or the meaning of them, they will not be able to pass the examination."

"Are we going to have an examination?" asked Flippy.

"Yes," said Lawrence, "and a very strict examination too. There are six of the hard words, but the last one you will not have to study, but only to practice, since it has nothing to do with heat, but only means that you must listen attentively to what I say. If you pay close attention to this lecture, I will give another some day, on deflagrations, detonations, and explosions."

"Good!" said Flippy, clapping his hands; "I should like to hear that lecture. *I'll* attend."

So he placed himself in an attitude of attention, while Lawrence proceeded:

"When heat shoots out from any hot body in streams through the air, or through space, the movement is called *radiation.* The streams are called rays. If you hold up your hand opposite this chimney you will feel the radiation from it."

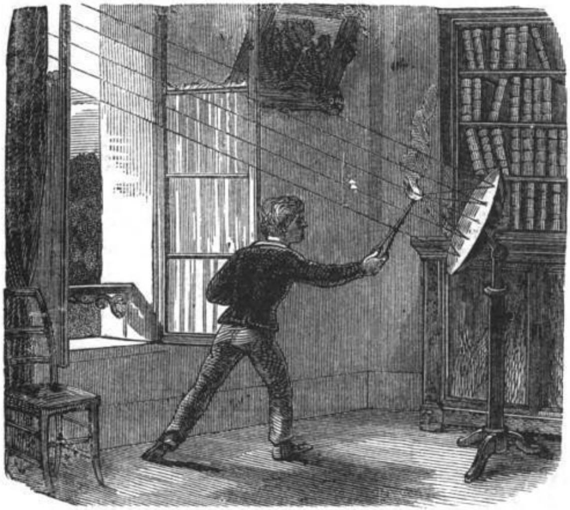
Flippy and John both held out their hands to verify this statement.

"Radiation is practically instantaneous," continued the lecturer. "If I hold a book in the way, so as to stop the radiation upon your hand, and then suddenly withdraw it, you will feel the heat shoot across to your hand instantly, even though it might be several feet off. The heat arrives to the earth from the sun instantly, as soon as the sun rises, though it has ninety millions of miles to come on its way. The quantity of heat that is radiated from the sun upon the earth every day is enormous. It entirely surpasses the power of the human imagination to conceive of the quantity. A great portion of it is employed in warming the earth and the air, and a great portion of it is expended in the leaves of trees, being there changed into force, which is stored up in the wood, and peat, and coal, which is formed from it, to come out again as heat in the future processes of combustion and decay. So don't forget what radiation is.

"The next word is *reflection.* If radiated heat strikes against a glass, or any polished surface, and it is the same, to some degree, with surfaces that are not polished, it is in part *reflected*—that is, it is made to bound back like a ball thrown against a wall.

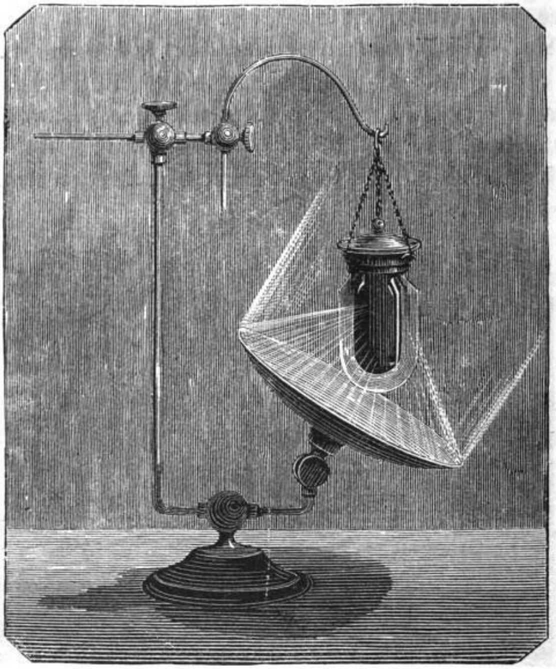
"When you let a sunbeam shine upon a piece of looking-glass, by turning the glass you can turn the beam of light in any way you choose. *That* is reflection. It is reflection of light. When you reflect the light of a sunbeam in this way, you reflect the heat too. We do not see the heat as we do the light, but it is there.

"If the mirror that reflects the heat is concave, then it will reflect it in such a manner as to gather all the rays to one spot, called the focus, and if you hold any combustible substance there it will be set on fire, showing that the heat has been concentrated in one point by reflection from the concave mirror.



EFFECT OF THE CONCAVE REFLECTOR.

"There is a story told of a philosopher in ancient times who set a fleet of the enemy on fire by reflecting heat from the sun, by a great many mirrors, against the side of one of the ships. Each mirror reflected a portion of heat, and all, united together, set the wood on fire. I have some doubt, however, whether the story is true. Some experimenters once undertook to heat water, and even to cook, by concentrating the reflected heat of the sun upon some kind of vessel.



COOKING BY THE REFLECTED HEAT OF THE SUN.

" At any rate, continued Lawrence," heat, like light, may be reflected—that is, turned back from its course by a mirror or a reflector of any kind. It may also be *bent* out of its course in passing through a transparent substance like glass.

"This bending of the rays of light in passing through a transparent substance is *refraction*, which is the third of the words that you have to remember.

"There is a kind of glass, thicker in the middle than at the edges, which is called a convex lens."

So saying, Lawrence drew from his pocket a small magnifying glass, and let his audience all see that it was thicker in the middle than at the edges.

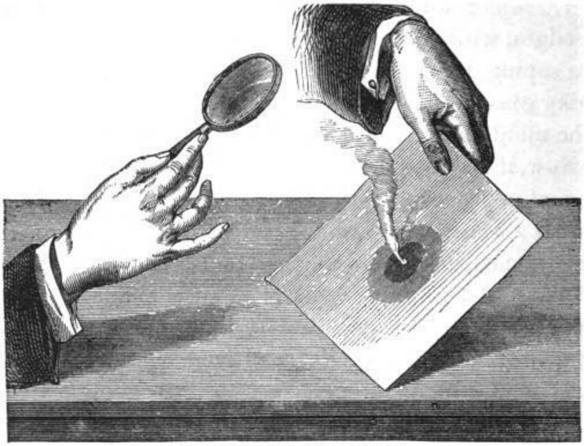
"Now, if the rays from the sun pass through this lens, ladies and gentlemen," continued Lawrence, "the outer ones would be turned inward toward the central ones, each being turned just in proportion to its distance from the centre, so that they will all meet at a point called the *focus*. You can see the focus of light, and if you let me throw the focus upon the back of your hand, you will feel the focus of heat."

This Lawrence did to Flippy, and Flippy felt the heat very sensibly.

"It is what they call a sun-glass," said Flippy.

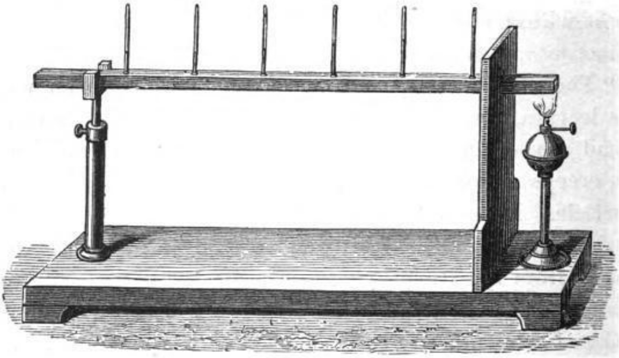
"Such a lens, ladies and gentlemen," continued Lawrence, appearing not to notice Flippy's remark, "is sometimes called a sun-glass; and if it is large and of a true form, and if the sun shines bright, the heat concentrated by it will be sufficient to set paper or cloth on fire. Boys sometimes flash gunpowder with it.

"The next word," continued Lawrence, going on with his lecture, "is *conduction*. Conduction is when heat, instead of shooting swiftly through space with great velocity, creeps along through any substance from particle to particle. If you put a flat-iron upon a hot stove and hold it there with your hand, at first you will feel the heat that comes from the stove by *radiation* on the outside of your hand. But the handle of the flat-iron will feel cool to the palm of the hand, and to the fingers that clasp it, until the heat has had time to creep along slowly through the substance of the iron itself, and after a time it will become so hot that you can not hold it. Heat creeps more easily and



EFFECT OF THE CONVEX LENS.

rapidly through the substance of iron than it does through many other substances. There is an experiment by which a gradual progress of the heat may be made very plain to the eye.



CONDUCTION OF HEAT.

"You take a bar of iron, and support it on a stand horizontally, so that you can heat one end of it by a spirit lamp. There are a number of holes in the upper side of the bar, in each of which a short wire is placed, the wires having been coated with wax by being dipped into melted wax beforehand. Here you see the apparatus itself."

So saying, Lawrence took out a piece of paper, and made a sketch showing the form and arrangement of the apparatus, with the wax melted at different heights along the tube, as the heat conducted along the iron reached them in succession.

"Some substances conduct the heat very readily and rapidly, and others very slowly," continued the lecturer. "Iron and most of the metals are good conductors; glass, ivory, wood, and air are very bad conductors. I will show you the difference between a rod of iron, which is a good conductor, and a pipe-stem, which is a very bad one."

So saying, Lawrence took John's hands and put them together as if he wished to make a receptacle to hold something.

"Here you see a bowl," he continued; "I am going to pour some boiling water into it."

So saying, he made believe pour water into the hollow which he had made by John's hands.

"Now," said he, "I will put a rod of iron and also a pipe-stem in the water, leaving the upper ends projecting out of the water by the edge of the bowl."

So saying, he put his pencil-case into the bowl, and also his knife, pretending that the pencil-case was the pipe-stem and the knife was the iron rod, and then asked Flippy, as one of the audience, first to touch the end of the pipe-stem, and then the end of the iron rod, to see how cool the former and how hot the latter was, on account of the difference in the conducting power of the two in bringing up the heat from the water. Flippy entered into the idea very readily. He felt of the end of the pencil once or twice, with an expression on his countenance as if it was quite cool. He then touched the end of the knife, but at once pulled his hand away, and began to blow his fingers as if he were burnt. Almira smiled at this novel mode of giving experimental illustrations of philosophical principles, while John laughed outright.

"When we wish to stop the flow of heat by conduction," continued Lawrence, "we put bad conductors in the way to intercept it. They fit a small piece of ivory or wood at the upper and lower ends of the handles of tea-pots and coffee-pots, to prevent the heat flowing too fast into the handle; and loose substances filled with air, such as woollen cloths, over our bodies, to keep the heat from passing out; and the same things, or straw and shavings, around ice, to keep the heat from getting in. Such things keep the heat from passing either way. There is no warmth in the substances themselves; they only keep what warmth there is on one side or the other of them from passing through.

"The next word in my lecture," said Lawrence, "is *convection.* Convection means the act of conveying, and this is the kind of motion of heat which takes place when the heat does not pass through the substance of itself from particle to particle, while the particles themselves remain at rest, but when the *particles themselves move*, and so convey it with them. It is in this way the heat is diffused through water. When you heat water in a kettle over a fire, the heat does not pass up of itself through the substance of the water, as it does through the substance of iron, but the particles that are on the bottom get hot, and then they move up in currents through the cold water above, and that comes down and gets hot in its turn, and so, finally, it all gets hot. This is the way that heat is diffused through the ocean and through the air, by warm currents of water and of air that circulate through the whole mass and carry the heat every where. Every warm breeze from the south is a current of convection, and so is every warm current in the sea. The Gulf Stream is probably the grandest example of a current of convection, and of the diffusion of heat by that method, on the globe.

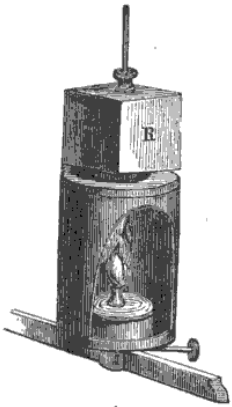
"And this is the last of the five words relating to the modes of movement of heat, namely, radiation, reflection, refraction, conduction, and convection, and this finishes my lecture."

There were many other things that Lawrence would have liked to explain in his lecture in respect to the five modes of movement observable in heat, but he noticed that the officers were upon the quarter-deck with their sextants, and he knew that they might at any time make it twelve o'clock, when the bell would be immediately rung for luncheon. There was one thing in respect to radiation that he did not have time to explain, which is very important—namely, that when heat radiates from a body, the quantity thus issuing from it depends not only upon the temperature of the body—that is, upon the internal condition as to heat—but also upon the *nature of the surface* from which the radiation takes place. The heat radiates much more rapidly, for example, from a rough or a dull surface than from a bright or a polished one. It is affected, too, very much by the nature of the material of which the body is composed.

The laws in relation to the effect of surface on radiation have been very carefully determined by the aid of a simple contrivance called Leslie's Cube.

The principle of this device is illustrated, in one form, by a cubical vessel of tin, the sides of which are in different conditions. One side is left polished, another is roughened by sand-paper, a third blackened with lamp-smoke. The cube is filled with water and put over a lamp, a slender tube being open above to allow of the escape of the steam.

Of course, all the four sides of the cube will be equally hot, but there will be found to be a very great difference in the amount of radiation from them.



LESLIE'S CUBE.

By means of cubes of this kind, in connection with the thermo-electric multiplier, by which very slight differences in the radiation can be measured, the whole subject has been very fully investigated, and many facts have been ascertained which are of great use to engineers, mechanics, and constructors of apparatus of all kinds in which heat is concerned. We know, without much nice observation, that a tea-pot, in order to prevent the radiation of the heat, and to keep the tea hot, must be bright and polished on the outside, while a stove or a stove-pipe, in order to *facilitate* the delivery of the heat developed by the combustion within, must be dull in surface, and is all the better for being black.

Lawrence might have included among the subjects connected with the transmission of heat, which he discussed in his lecture, that of absorption, which would have been another hard word for Flippy, and which refers to the *receiving* of heat by the surface of any substance upon which it is projected by radiation, and to its being taken in, or *absorbed*, by the substance itself. The character of the surface affects the amount of absorption very much as it does the radiation, as is shown by the common experiment, easily performed, of putting bits of different colored cloth upon the snow on a bright spring morning, and observing how much faster and how much deeper some melt their way down into the snow than others.

He did not have time to enter into these topics, but, before dismissing his audience, he asked the boys some questions by way of examining them on the subject of the lecture, and when they came to refraction, and to the phenomenon of the rays of heat being brought to a focus by passing through a convex lens, he gave them an account of a small cannon which he said there used to be in the garden of the Palais Royal, in Paris, with a lens fixed above it in such a position that precisely at noon the focus of the lens should come over the powder at the touch-hole and fire the gun, thus giving notice to all the people in all the shops, and restaurants, and galleries around that it was noon—that is, noon by *solar* time.

THE NOON GUN OF THE PALAIS ROYAL.

Just as the party had reached this point in Lawrence's explanation, eight bells were struck at the quarter-deck, and the officers went below with their sextants. The striking of eight bells was immediately repeated on the forward deck, and a moment afterward the bell announcing lunch was rung below. Flippy said he was sorry, as he wished to hear about explosions, but Lawrence promised to tell him about that at some future time.

"Only," said he, "we can not have illustrative experiments for a lecture on that subject at sea, as the only explosion to be thought of on board a steamer is the bursting of the boiler, an illustration of the subject which I hope we shall be spared."

CHAPTER XXVII.

SCIENTIFIC TERMS EXPLAINED.

THERE are a great many very remarkable things connected with the characteristics and the action of heat in the economy of nature which would require a great deal of study to comprehend in all their bearings and relations, but which, in respect to the general principles involved, are easily enough understood. One of these things is the philosophy of explosions.

EXPLOSIONS.

Explosions, so far as they are produced by the sudden evolution of heat by combustion—which are all that we have to do with in this volume—are effected simply by the *rapidity* with which the process of combustion is carried on. When the combustion is extremely rapid, but not sensibly *instantaneous*, we call it a *deflagration*, as, for example, when gunpowder is burned in the open air. We call it an explosion when the combustion and the force which the heat develops are sensibly instantaneous, as when gunpowder is burned under pressure by means of which the heat developed by the first portions burnt takes effect instantly in igniting the rest, and so hastens the whole process.

Now, combustion being only a violent chemical action, consisting usually of the combination of carbon or hydrogen with oxygen, the rapidity of it depends mainly upon how readily the carbon or the hydrogen finds oxygen at hand to combine with it. If you lay a log of dry wood on the fire, it burns slowly, because the inner portions of it are shut out from the access of oxygen, and can only be reached by it as fast as the outer portions are burnt away, and they can be burnt away only so fast as they can derive oxygen from the air. You can hasten the process by sending air in more rapidly by blowing the fire, and you could hasten it very much more if you send in upon it a stream of oxygen, instead of air, of which the oxygen forms but a small part. Still, even in this case the inner portions could not be reached by the oxygen except so far as the outer ones were burnt away.

But if now we divide up the log of wood into shavings by means of a plane, and put the heap of shavings on the fire, we have the same substance as before, and the same process of combination with oxygen to go on; but it will be greatly facilitated now by the oxygen of the air having much more easy and intimate access to it through the openings between the shavings, and the finer and thinner the shavings are, and the more lightly they are laid together, the more rapid the combustion will be. But it will not be instantaneous, for every shaving, however thin, has *some* thickness, and the interstices, moreover, will not contain oxygen enough for a full supply.

But if, instead of wood, we take the hydrogen in the form of a gas, and mingle it with air—or, what would be still better, with oxygen, in the proper proportions, so that each particle of hydrogen shall have the oxygen that it requires close at hand—then the combustion, when once commenced, would be practically instantaneous, constituting an explosion. This is what happens in coal-mines when the gas issuing from fissures in the coal becomes mingled with the air in the right proportions, and then the process of combustion is commenced by the lamp of the miner raising a portion of the mixture to the right temperature for the combination to begin.

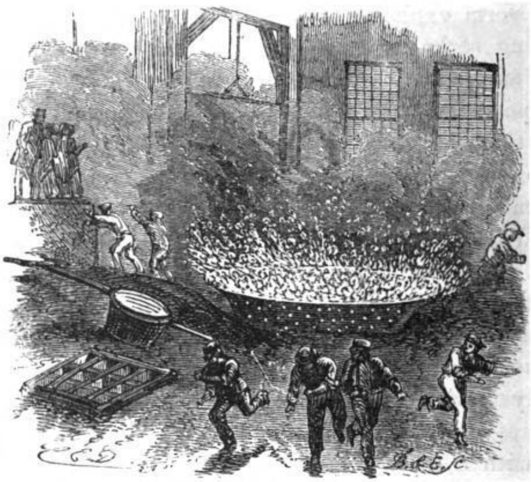
EXPLOSION IN A COAL-MINE.

To form explosive combinations for practical use—in blasting rocks, for example, or for fire-arms—we require some substance in a *solid* form, as gases are too bulky for transportation, or even for easy management when we have them at hand.

Now oxygen can not exist in a solid form except when in combination with some other substance. The thing required then, obviously, is to find it in a solid form combined with some substance that holds it most loosely, and will most readily give it up for the purpose of combustion. That is the philosophy of gunpowder. The saltpetre is the substance that contains the oxygen, holding it, however, so loosely that it very readily gives it up. The sulphur, which inflames at a low temperature, begins the work of combination with it when the spark is applied, and the charcoal, which in the act of combination gives out great heat, completes the work. If the gunpowder is burnt under pressure, as it is when it is tamped into the rock or rammed into a gun, the intense heat, acting upon the compressed gases produced by the combustion, develop the vast force that is produced by the explosion.

Thus in almost all, or, at least, in a great many detonating, fulminating, and explosive substances, the secret is a *supply of oxygen close at hand for rapid combination with a combustible*, the supply being contained in some solid substance in which the oxygen is held in combination with an element that holds it by a very weak affinity, so as to be ready at any moment to let it go. The element which has most frequently this function to perform is *nitrogen*, which seems to be a great *loose-holder* in the economy of nature, as oxygen is a great *strong-holder*.

There are many other kinds of chemical action, it is true, that are so sudden and violent as to produce explosive effects besides those in which oxygen is the principal



EXPLOSION IN A FOUNDERY.

agent, and chemical laboratories are subject sometimes to very serious accidents when substances of this kind are accumulated in them in large quantities. One of the most serious accidents of this kind occurred only the last year in Paris by an explosion in a laboratory in the midst of the city, from the effects of which many persons were killed and great damage was done.

SPECIFIC HEAT.

Another very remarkable principle in regard to the action of heat is to be observed in the fact that it requires very different quantities of heat to raise the same weight of different substances to the same temperature. Bring a pound of water and a pound of marble from the cool air out of doors into a warm room, and it is found that the water will take in five times the quantity of heat in coming up to the temperature of the room that the marble will require. It will absorb about *ten* times as much as

EXPLOSION IN A LABORATORY.

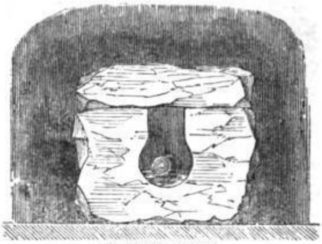
M

iron, and about *thirty* times as much as lead. One would suppose that the same quantity of heat would raise the same quantity of different substances to the same temperature, but the fact is far otherwise. There is no correspondence at all in the effect produced, whether we consider the weight or the bulk of the substances compared. Mix hot and cold water together in equal weights, and the mixture will be of exactly an intermediate temperature. So with hot and cold mercury. But mix cold water and hot mercury, and the water will scarcely be warmed at all, on account of the small quantity of heat which the mercury requires to make it hot.

That constitution of a body on which the quantity of heat which it requires to raise its temperature depends is called its *specific heat.* The specific heat of water is very high; that of iron about one tenth that of water; that of silver *one half* that of iron; that of copper only *one fifth* that of silver. The cause of these differences is a great mystery.

Of course, the amount of heat which these substances absorb in being raised to a given temperature is given out again when they are cooled, and this furnishes an easy mode of comparing the specific heats of different substances by observing how much heat they give out in being cooled. One curious way of determining this is by seeing how much ice they will melt. Suppose several balls of different metals, but of the same weight, are put into an oven and heated all alike. They are then severally put into holes made in a block of ice, and covered with another block of ice placed above in the manner shown in section in the engraving on the following page.

After remaining till they are cold, the water which each one has produced by the liquefaction of the ice is taken out and weighed, and in this way the comparative amount

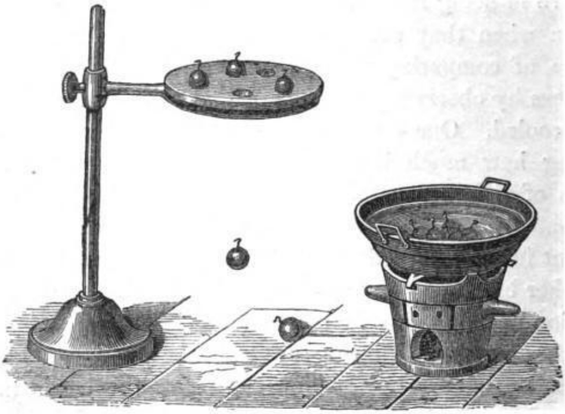


THE ICE-CHEST.

of heat which was derived from the cooling of the several balls from the temperature of the oven to that of melted ice—namely, 32°—is exactly ascertained.

This difference in the specific heat of different metals is sometimes shown, for illustration, by means of wax instead of ice. A number of small balls of different metals are heated in a vessel of water, being thus all raised to the same temperature. They are then taken out and placed upon the circular cake of wax, as shown in the engraving.

It will be found in such a case that, though the balls were all of the same temperature when taken from the



THE CAKE OF WAX.

water, some have heat enough in them to melt their way through the cake of wax and fall down upon the floor, while others, whose capacity for heat is less, have only imbibed enough from the water to melt their way partly through the cake of wax, when their farther progress is arrested by the failure of the supply they had in store.

Water has a very great capacity for heat compared with most other substances. For this reason, a bottle of hot water is an excellent thing to put to the feet of a sick person to keep them warm during the night, inasmuch as the water has a larger quantity of heat in store than most other substances of the same weight would have if heated to the same temperature. It contains about five times the quantity that could be stored in an equal weight of marble. How it is with soapstone I do not know. The way to ascertain, or, at least, one way to do it, would be to heat a block of soapstone, and also an equal weight of water, to the same degree in an oven, and then, by placing them both in holes made in ice, observe which melts the greatest quantity of the ice in becoming cooled.

HEAT OF LIQUEFACTION.

There is another very remarkable phenomenon connected with the action of heat, which is not only very curious, but is of fundamental importance to be understood. It is this, that what is called the *heat of liquefaction*—by which is meant the heat that is absorbed and becomes latent in changing a body from the solid to the liquid state—is very different in quantity for different substances. It requires one hundred and forty units of heat to the pound to liquefy water, for example, all of which quantity disappears as heat in the process, and is employed as a force to maintain the water in its liquid state. But to liquefy lead only *seven* units to the pound is required. It is true that lead does not begin to liquefy until it has reached a much higher temperature than is necessary for water, but when it has reached that temperature and begins to melt, it absorbs a *much smaller quantity in the process of melting.*

This difference is very perceptible in fact to common observation. For lead, when it begins to melt, melts very fast, while ice melts slowly, on account of its requiring so much more heat to make the internal change; and so lead solidifies again much more rapidly than water, as it requires only the abstraction of seven units of heat to the pound, whereas one hundred and forty units — that is, twenty times as much — must be drawn off for the water. If a boy melts a pound of lead in a ladle, and draws it back from the fire a little way, it all hardens very rapidly; but it takes a long time for a pound of water to freeze, even though it is put in a place as much colder than its point of congelation as the air around the ladle was colder than the point of congelation of the lead.

Thus each substance requires its own special quantity of heat to liquefy it, the amount being very different for different substances; but for the same substance, under the same circumstances, it is always rigidly the same.

DIATHERMANCY.

Lawrence might have included this word among those hard to be remembered that he taught the boys. It bears the same relation to heat that *transparency* does to light; that is to say, that as the word transparency denotes that property of a body which allows light to pass through it, diathermancy is that which allows heat to pass through it. We may say, in fact, that while the word transparency means, etymologically, *shining* through, diathermancy means *warming* through.

We have a general idea that those substances which are transparent are also diathermant, but it is not so in all cases by any means. A plate of glass, for instance, held between your face and a stove, will allow the light to pass freely, but will intercept nearly all the heat—that is, you can see the stove through it nearly as well as through the air, but you will not feel the warmth through it.

And yet the plate of glass which intercepts the heat from the stove will allow the heat from the sun to pass through it very freely. And this is found to be owing, not to a difference in the intensity of the heat, but in some mysterious difference in the kind or quality of it. The rays of bright heat from the sun are called *luminous* rays. The rays of dark heat from a stove not red-hot are called *obscure* rays. There are found to be very curious differences in the action of these different rays, which lead sometimes to very remarkable and very important results.

For instance, in a conservatory, or in a gardener's hot-bed, or a room with windows toward the south, or any other such inclosure with access to it through glass for the rays of the sun, the air inside will become much warmer than that surrounding it on the outside, because the luminous rays *can come in* through the glass. But when they strike the ground they are absorbed and warm the ground, and then, when the ground begins to emit a radiation, the rays are obscure rays, and so *can not go out* through the glass. Thus the heat is caught in a trap, as it were, and imprisoned.

If, therefore, in the spring, you put a box, open at top and bottom, over some seeds that you have planted in your garden, and put a pane of glass over the top, you literally set "a trap to catch sunbeams" for the benefit of your seeds.

It is very certain that the conditions in the internal constitution of a substance on which the transmission of light depends are very different from those which favor the transmission of heat. Rock salt, for example, and alum, are nearly *transparent*, but a plate of rock salt of a certain thickness—one tenth of an inch—will allow almost the whole of the heat to pass with the light, while the alum, without stopping the light, will intercept almost the whole of the heat. The salt will transmit *nine* tenths, and the alum only *one* tenth of it. A plate of water, so to speak, such as may be formed by filling the space between two thin plates of glass placed a third of an inch apart, will intercept a very large portion of the heat, though it is almost completely transparent in respect to light.

On the other hand, *black glass*, and a mineral called smoky quartz, will allow nearly all the heat to pass through them, while they almost entirely intercept the light.

There are a great many other curious facts connected with the subject of diathermancy which greatly interest all those who have the time and opportunity to make themselves acquainted with them. They bring to view distinctions in heat analogous to those of color in light. These "heat tints," as they are called, are abundantly proved, though they do not affect our senses directly. We have no senses adapted to be affected by them. But there is no presumption against the idea that other animals, and especially insects, may have such senses. And this may possibly be a key to the mystery of the numerous inexplicable members and organs which many insects and other animals of the invertebrate classes possess, and of many strange and otherwise unaccountable phenomena presented to us in their habits, instincts, and modes of life. Heat and other radiations from the sun, imperceptible to us, may, in their various forms and conditions, be as fruitful and as varied a source of sensations to them as light is to us in its endless metamorphoses.

CHAPTER XXVIII.

THE SEA-BIRDS.

Special provision is often made, on board the great Atlantic steamers, to furnish the children that may be on board with means and facilities for play. This is very important. Indeed, one of the first necessities for children while they are growing, whether on land or at sea, is plenty of play. Work, although, considered as exercise, it might, perhaps, be regarded as much the same thing, will not really answer the same purpose. The reason is that work brings into action only the muscular system, while it is equally important to exercise, and so aid in developing, the functions of the nervous system and the brain.

Study, it is true, serves to call into action the nervous system and the brain, but, as it is ordinarily exacted, it does not do this in the gentle and agreeable manner necessary for producing the best effect in respect to the healthy development of the embryo powers. In order that children may grow well, and secure a healthy and symmetrical development of all their powers, they must have plenty of play.

But play, important as it is, is by no means all that they require. There are certain powers and faculties of the mind which are not much exercised in play, and which yet must be exercised in order that the progress of their development may keep pace with the growth and advancement of the system in other respects. Now this class of faculties can only be called into action by study—that is, by thought and reflection. Thus we see that the object of study for young persons is not merely the acquisition of knowledge. There is a still greater advantage derived from it when it is properly pursued, in promoting the development and growth of the higher powers and faculties of the mind.

In respect to the number and variety of the plays which can be made available on board ship, the range is somewhat limited on account of the motion. Rolling nine-pins, for example, would be utterly impossible at sea. So would any kind of game of ball, or battledoor and shuttlecock. Any thing like pitching quoits, too, would be out of the question, on account of the damage which such games would do to the decks.

There are various games, however, which can be played without encountering these difficulties. The sailors usually rig up a swing somewhere, when there are children on board that desire it; and there is a game of tossing rings, which consists in seeing how many rings out of a dozen you can make catch over a short iron bar set up in an upright position in the middle of a small, square piece of plank. The boys and girls, too, often play "I spy," running about the decks, and seeking for hiding-places behind the masts and rigging, or dodging about among the settees, and chairs, and camp-stools occupied by the passengers on the decks. As it is not possible for the children to go "out of doors" to play when they are on board a steam-ship in the middle of the Atlantic, all reasonable passengers are very indulgent in allowing them great liberty in coming with their play to the places where they are talking or reading, even though it should now and then cause them some interruption.

One evening, near the end of the voyage—it was, in fact, when the steamer was approaching the Irish coast—the boys and girls had been playing upon the deck for some time, when John observed that his cousin Lawrence, who was seated by himself near the stern, had his paper and pencil out, and seemed to be drawing something. John was standing at this time with a boy named Lionel, and a girl named Louise, near the great sky-light, during a pause in the play.

"Let's go and see what my cousin Lawrence is doing," said he; "he is making some kind of a picture, but there is nothing that I see but water and sky for him to draw."

"Yes," said Louise, "there are some gulls. Perhaps he is drawing one of them."

They all at once went to the place where Lawrence was sitting. He was, indeed, making a picture of a gull just in the act of swooping down to pick up something from the surface of the water.

"Is it a fish," asked Louise, "that he is trying to catch?"

"It may be a fish," replied Lawrence, "or it may be something that he can eat which the stewards have thrown over from what was left at the table."

These gulls go out to the distance of several hundred miles from the land, and follow the ships and steamers sometimes for a long distance, watching for what may be thrown overboard by the sailors, and also, probably, for the chance of catching some of the fishes which are enticed into following the vessel by the same temptation.

Lawrence was very skillful in the use of his pencil. He had begun to acquire this art when he was quite young. His first attempts were somewhat discouraging, as the results did not satisfy him at all. Most children, when they find that they can not make pretty pictures at once, give up in despair. But Lawrence said to himself,

"I can not expect to be able to make good pictures till I have learned. Others can learn, and why can not I. I mean to persevere."

And he did persevere. From time to time, when he had leisure, he practiced drawing. First he copied pictures of buildings from engravings in books, and then, as he acquired more skill, he took for his models figures of men and of animals, which were much more difficult.

The three children stood a few minutes looking over Lawrence at his work, when Lionel at length asked what the gulls were doing.

"They are taking in their coal," said Lawrence, gravely.

"Hoh!" exclaimed Lionel, "they can't eat coal!"

Lionel thought that what Lawrence meant was that the gulls were picking up bits of coal from the cinders, and other refuse from the furnace, that the men were throwing overboard from time to time.

"No," said Lawrence; "and perhaps I ought not to say exactly that they are taking in their coal, for they are not doing that literally. They are taking in that which serves the same purpose for them that coal does for our engines. It would be more strictly correct to say that they are taking in their fuel."

"Come, Louise," said Lionel, "let's go and play."

"No," replied Louise, "I am going to stay and see Mr. Lawrence finish the bird."

"Then *you* come, John," said Lionel.

"No," replied John, "I am going to stay too."

John was influenced by two considerations in deciding to stay. One was his wish to be with Louise, and the other he desired to have Lawrence explain what he meant by the gull's taking in fuel. As for Louise, she was a charming girl, and was a great favorite among all the boys and girls on board, not only on account of her beauty and accomplishments, but also, and more especially, on account of her gentle and affectionate disposition, and for the kind regard which she manifested for the welfare and happiness of the

LEARNING TO DRAW.

others. If any difficulty or trouble occurred, she always contrived some way to remedy or to remove it. If any body seemed to be neglected, she paid them attention, or if hurt, she helped and comforted them. She was a very pretty girl too, and was always very neatly and prettily dressed.

John was interested, moreover, in what Lawrence had begun to say about the gull being employed in taking in fuel, because he knew something about fuel as a source of power, and was very naturally desirous of hearing more. Lionel knew nothing whatever on that subject, and was, accordingly, not curious about it. Louise was not curious about that either, but she wished to remain in order to see Mr. Wollaston draw.

"I don't know that I ought really to call it fuel," said Lawrence, "that the gulls are taking in, for, in common parlance, we only apply that term to substances which, in developing heat and power by combining with oxygen, do it with so much violence of action as to produce *incandescence*—that is to say, fire. What the gulls take into their stomachs from the water corresponds to the coal put into the furnaces in three cardinal points.

"1. It consists of carbon, hydrogen, and other substances which have been deoxydized by the power of the sun in the leaves of plants.

"2. The essential change which takes place in these substances within the bodies of the birds is the reoxydizing of them, and the setting free in this way the heat and force which was originally stored in them by the sun. And,

"3. All the warmth in the bodies of the birds, and all the prodigious strength which they display in their long flights or in their swooping plunges at their prey, comes from this reoxydizing of this food, or of portions of the tissues of their bodies formed from it, just as all the heat in the furnaces and chimneys of the ship, and all the force by which the ship itself is propelled over the sea, comes from the force stored in the coal, and liberated by the reoxydizing of it in the fire."

Lawrence had explained this principle before, in relation to other animals, in his conversations with John, but John was only prepared on that account to be the more interested in it in its application to the case of the sea-bird, which exerts so enormous a strength in proportion to its size, and which requires so sure and constant a supply of warmth under the continued and extreme exposure it must undergo from wintry winds and driving storms far out at sea, where there is no possibility of shelter.

"In a philosophical point of view," continued Lawrence, "there is only this difference between the manner in which the ship and the bird receive their heat and their power, and that is that in the body of the bird the reoxydation of food is effected by a process that is comparatively gentle, while in that of fuel in the furnaces of the ship it is very violent and intense. The *whole amount* of heat and of power developed by the oxydation of a given quantity of the material is precisely the same in both cases, only when it is used as fuel the amount is given out in a briefer period, and so is more intense."

"But, Lawrence," said John, when his cousin had made these explanations, "if the food which animals take is only a kind of fuel for them to give heat and force by its being reoxydized in their bodies, why won't any common fuel do for them for food? Why can't they eat wood and coal, as well as meat and corn?"

"Because their machinery is not adapted to it," replied Lawrence. "Different kinds of machinery are adapted to different kinds of sustenance. The furnaces of this ship are adapted to burn English coal, which is the bituminous kind; in America they are often arranged for anthracite coal or for wood. And not only so, but the engines and all the machinery are fitted to be driven by heat and by force in the form in which they are developed by *combustion*, whereas the muscles, and nerves, and all the other internal machinery of the animal system are fitted to be worked by heat and force in the form in which they are furnished by the process of *digestion*."

John was interested in these remarks of Lawrence because he already knew enough to understand them. But Louise did not understand them very well, and so she did not pay so much attention to them, but stood looking at Lawrence's work. He drew several gulls in different positions, as they plunged toward the water, or just skimmed the surface of it, or rose again into the air. Just as he had finished saying to John what is related above, it happened that one of the stewards threw out a wisp of hay or straw which he had perhaps taken from an empty Champagne-basket, and, as the wisp floated astern, two gulls alighted upon it together, and Lawrence immediately began to sketch the group. Louise asked him to give that picture to her when it was finished. Lawrence said he would do so, and that he would, moreover, finish it for her with special care.

"I wish *I* could draw," said Louise.

"Well," replied John, "you can easily learn."

"No," rejoined Lawrence, "not easily. She can learn, but not easily. It is not a quick or an easy thing to learn to draw."

"It takes a great deal of time and pains, I suppose," said John.

"Not exactly so," replied Lawrence. "It takes a great deal of time and pleasure—that is to say, according to *my* experience."

"I should like to learn," said Louise; "and I would learn if I had any body to teach me."

"You don't need any body to teach you," replied Lawrence. "All you have to do is to make a little book of common paper, not ruled, and when you are at leisure, instead of sitting still and wishing that you had something to do, take your pencil and copy parts of pictures out of any picture-book as well as you can."

"Why not whole pictures?" asked Louise.

"It is very well to take whole pictures," said Lawrence, "if your object is to show off, and let other people see what you can do, and get praised for it. But if your object is *to learn*, you had better take at first only parts of pictures, such as a gate, a steep bank, a boat, one side of a house, or even a door or a window. In this way you can study the lesson better."

"Study the lesson?" repeated Louise, not knowing exactly what Lawrence meant.

"I mean by that," replied Lawrence, "study the drawing, or part of the drawing that you are going to copy, so as to see by what kind of strokes or touches particular effects are produced."

Louise did not reply to this, but in her heart she resolved that she would make a little book and try.

"If you do this, and persevere," said Lawrence, "you will make a great deal of progress in cultivating your eye and in practicing your hand, and then, when you finally see any person who knows how to draw well, he will give you some advice and instruction that you will be prepared to understand and profit by."

"I mean to do it," said Louise.

"Yes," replied Lawrence, "you mean to do it, but I don't really think you will; at least I should not think so if you were a boy."

"Why not?" asked Louise.

"Because boys," said Lawrence, "though they are willing to try hard and to work very perseveringly to learn any thing that is useless, commonly get tired very quick if it is any thing useful. They will practice incessantly, of their own accord, in order to learn to walk on stilts, but they are very seldom seen trying voluntarily to learn to write. They get off from their music-lesson whenever they can, but there is no end to the patience and perseverance they show in learning to catch a ball, or to manipulate jackstones, or to acquire any other utterly useless accomplishment."

"But, Lawrence," said John, "I don't think these things are utterly useless."

"True," replied Lawrence, "perhaps they are not utterly useless, but, at any rate, dexterity in them is not likely to be quite so useful in future life as skill in music or drawing."

CHAPTER XXIX.

OXYGEN AND THE TELEGRAPH.

"It is very curious," said Lawrence, as John and Louise sat by him, one on each side, upon the settee, overlooking his drawing—"indeed, it is wonderful how large a proportion of the work that is done and the effects that are produced in the world results from the reoxydation of substances which have been previously deoxydized—that is, from the force with which oxygen seizes again substances from which it has been separated. For instance, there is the action of the electric telegraph. Did you know, Louise, that there was a wire under us here at the bottom of the sea that is conveying messages back and forth between Europe and America?"

"I knew that there was a wire somewhere," said Louise, "but I did not know that it was under us here."

"I don't know myself that it is exactly under us at this spot," said Lawrence, "but it can not be very far from us, for we are drawing near to the coast of Ireland, and at a place not a great way from where the wire leaves the shore."

"How far down is it, through the water," asked Louise, "to where the wire is lying?"

"From half a mile to a mile, I suppose," said Lawrence, "though I do not know exactly the depth. The curious thing about it, as I was saying to you, John, is that the source of the power by which the telegraph is worked is substantially the same, in its nature, with that by which the engines of the ship are driven—namely, the intense energy with which oxygen rushes to a reunion with a substance that has previously been separated from it. In the case of the steam-engines, the substance is carbon, or, rather, a combination of hydrogen and carbon; in the case of the telegraph, it is zinc.

"There are two differences, however, in the two cases. First, in the case of the carbon and hydrogen, the oxygen was originally separated from them by the heat and chemical action of the sun in the leaves of plants, while it was separated from the zinc by the heat and chemical action of the fire in the furnace in which the zinc was smelted from the ore; and, secondly, the force resulting from the reoxydation of the hydrocarbon appears as mechanical motion, while that coming from the zinc is in the form of electrical energy. The force is prodigious in both cases. In the one, it turns paddle-wheels with so much power as to drive an immense ship, with all its machinery, and passengers, and cargo, at great speed through the stormiest seas; in the other, it sends a succession of electrical impulses every second through three thousand miles of wire at the bottom of the sea."

"I never could understand very well how they could send messages by the telegraph," said Louise.

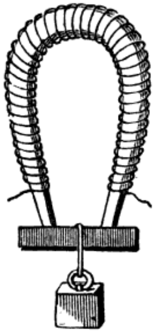
"I will explain it to you," said Lawrence. "I can explain it so that you can understand it pretty well—at least so far as to have a general idea of the principle. But I must make a picture of it first."

So saying, Lawrence laid aside his pictures of the birds, and, taking another piece of paper, he proceeded to make a drawing of the instrument by which telegraphic messages are received. He did it quite rapidly, describing the several parts as he went on.

"But first," he said, "you must understand one very remarkable fact on which the whole action of the telegraph depends, and that is that you can make a bar of iron strongly magnetic in an instant, at any time, by passing an electric current through a wire wound around it; then, by stopping the current, the magnetism will almost instantly cease. It is no matter how far off the battery may be which produces the current. The electricity may be brought any distance by means of wires, and, as it may be sent in series of impulses longer or shorter, and combined in any way, the operators can make an iron bar pull as a magnet, and let go its hold alternately, just as they please, no matter at what distance it may be from them. So you see all that they have to do is to agree upon a certain mode of pulling and letting go for every letter of the alphabet, in order to enable them to spell out any words or any messages they please."

Here Lawrence made upon the margin of his paper a little drawing of a bar of iron, bent somewhat in the shape of a horseshoe, with a wire round it, and a cross-bar of iron with a weight suspended from it, and held there by the attraction.

"The electric current is passing round now," he said, "and that makes the iron strongly magnetic. If one of the wires were separated from the magnet, the magnetism would cease in an instant, and the weight would drop."

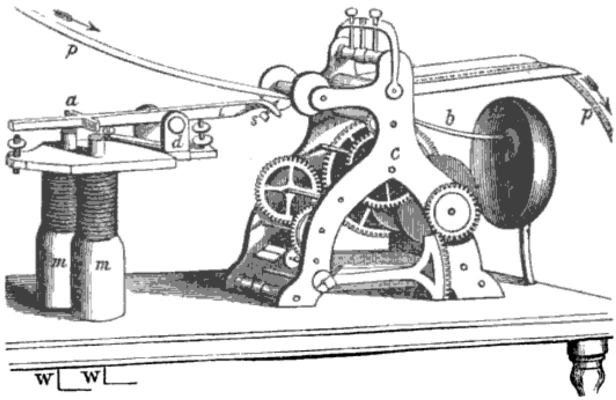


HORSESHOE ELECTRO-MAGNET.

The chief force of a magnet, as the reader probably knows already, is manifested at the two extremities, which are called the poles; and the bar which is wound with the wire, and is to be made magnetic, is bent in this form so as to bring the two poles together, in order that they may help each other in the lifting. A magnet made in this form is called a horseshoe magnet. And if the magnetism is produced by a current of electricity carried round it in a coiled wire, it is called an electro-magnet.

Having thus explained the general principle on which the system operates, Lawrence described the several parts of the apparatus, pointing them out upon the drawing which he had, in the mean time, been making. He made it from recollection, having seen such an engraving in a book. His drawing was well calculated to give a clear idea of the general principle on which the telegraph is worked, though the apparatus is, in fact, much more complicated than was represented in it; and it varies, moreover, very much in its form in different places where telegraphs are in operation.

You can obtain a good idea of the drawing which Lawrence made, and of the principle on which the telegraph operates, by this engraving. The long and narrow band,



ACTION OF THE TELEGRAPH.

p, which comes down in the direction of the arrow on the left, and then, after passing through the machine, goes up the slide, and so down in the direction marked by the second arrow on the right, is the paper on which the message is marked. It is drawn down through the machine by two rollers between which it passes, and which are made to revolve slowly all the time, while the machine is in operation, by the clock-work which you see in the central and lower part of the apparatus. All the use of that clock-work is simply to draw the band of paper along, in a slow and steady manner, as it receives the marks which form the message, and which are all made by the simple mechanism on the left.

The marks by which the message is spelled out consist simply of dots and dashes. Thus a dot and a dash, like these, . —, mean *a*; a dash and three dots, thus, — . . . *b*, and so with all the other letters, the simplest combinations being assigned to the letters most frequently used. These marks are all made upon the band of paper as it is slowly drawn along by the rollers. They are made by the little pencil seen at *s*. If this pencil merely touches the paper and is at once withdrawn, it makes a dot. If it is pressed against the paper, and held so for a moment while the paper is drawn along a little way, it of course makes a dash.

And now for the manner in which the pencil is made to be alternately pressed against the paper and withdrawn from it. You will see, by looking at the engraving, that it is fixed at the end of a somewhat long bar, *l*, which bar is poised upon a pivot near the middle of it at *d*. At the outer end is a cross-piece, *a*, and it is plain that when that cross-piece is drawn down, the pencil end will be pushed up; and as long as the cross-bar is held down, the pencil will continue to make a trace upon the band of paper as the band is drawn along above it.

Now directly under the cross-bar are the two poles of the horseshoe magnet, *m m*, with the two wires below which form the connection with the electrical battery, perhaps hundreds of miles away. Of course, when the operator at the distant station makes the connection, and sends an electrical current through the wire, the electro-magnet becomes magnetized, the cross-bar is drawn down, the pencil is pressed up, and a dot or a dash is made upon the paper, according to the length of the time during which the electrical current is allowed to flow. Thus the operator, by sending a succession of electrical impulses of longer or shorter duration, can cause any succession of dots and dashes he pleases to be made upon the long paper band, although he may be himself hundreds or even thousands of miles away.

"So you see," continued Lawrence, after he had finished his explanation of his drawing, "that if we could go down to the bottom of the sea, where the telegraphic wire is lying, and could examine it, and if we had senses that were of the right kind, and were sufficiently acute to enable us to perceive what is going on upon it, all that we should find would be a series of electrical impulses, some longer and some shorter, running with immense velocity along it, from America to Ireland, or from Ireland to America.

"And the curious thing about it, John," continued Lawrence, "is that the source from which all these electrical impulses are derived is the same that we have seen originating power in so many other ways—that is, the devouring energy of oxygen; only what he devours in this case is zinc instead of carbon and hydrogen.

"And there is one thing curious for you, Louise, in the way in which it was found out that a current of electricity, in passing through a wire wound round an iron rod or bar, would make it suddenly a magnet. A philosopher who was making some experiments one day observed accidentally that when a current of electricity passed along a wire *over a magnetic needle*, it caused it to turn in a very singular manner. Many people might have thought that no possible good could come from such an apparently insignificant fact as this, and would not have investigated it. But those who first observed this phenomenon did not think so. There were many persons among them who became much interested in investigating it. They ascertained before long, among a great many other things, that an electrical current carried round a bar of iron would make it a magnet, and that the magnetism would suddenly cease as soon as the current was interrupted; and the whole science of telegraphy has grown out of this discovery.

"So you see the best thing for us to do is to learn every thing we can. We never can foresee in how many ways knowledge will be useful to us. I never thought, when I was learning to draw, that I was procuring myself the pleasure of one day making pictures to amuse and instruct you and John on board a steamer crossing the Atlantic."

Lawrence now said that it was drawing near to the time for tea, and so he rose from his seat to go below. John and Louise remained upon the settee. A moment afterward Lionel and some other children came up to propose a plan for having a game on the decks the next morning before breakfast. Just at the same time the major came along, and stood there a moment listening to their talk about it.

"Only I can't come before the first bell rings," said Lionel. "My mother is not willing; she says the decks are wet."

"And *we* can't hear the first bell," said Louise, "in our state-room, it is so far off."

"Then I'll come and tell you when it rings," said John, "and guide you up; and you must be on my side in the game."

"No," said Lionel, "I want Louise to be on my side; won't you, Louise?"

Louise looked somewhat perplexed at being the object of this rivalry, and seemed hardly to know what to say. At length she answered timidly, "Whichever of you come for me."

"Good!" said Lionel; "I'll be sure to be there."

"Only you must not come before the first bell rings," said Louise; "I can't come out till then."

So it was agreed that Louise was to come with the one who was ready to wait upon her. They also asked the major whether he thought there was a prospect of a pleasant morning.

"Yes," said he, "an excellent prospect. But if you make appointments, any of you, and expect to keep them, I advise you to look sharp about the time, for we shall make the land some time during the night, and when we do we shall very likely jump to Greenwich time."

So saying, the major walked away.

"What does he mean?" asked Lionel.

"Why, I'll tell you," said John. "You see—"

"I don't care about knowing, after all," interrupted Lionel. "It is all about navigation, I suppose, and I don't expect ever to be a sea-captain."

So saying, he walked away, and the bell just then beginning to ring, the whole party went down to tea.

CHAPTER XXX.

JUMPING TO GREENWICH TIME.

John knew perfectly well what the major meant by the "jumping to Greenwich time," which he supposed would take place as soon as the steamer should make the land. Inasmuch, as has already been explained, the time at any part of the earth's surface is determined by the position of the sun in relation to it, of course, in going from place to place in an easterly or westerly direction, the clock must be changed from day to day, because the sun arrives earlier at a place lying to the eastward, and later at a place lying to the westward; therefore, in going to the eastward, the clock must be put forward every day, and in going to the westward, backward. Going to the northward or to the southward of course makes no difference.

They generally, at sea, make the change in the ship's time for each day at noon, both for the convenience of doing it at that hour, and also because noon is the time when the officers make the principal observations and calculations on which the determining of the ship's place depends. At no other time of the day do they ascertain so exactly where they are. So they set the clocks at noon, according to the time of the place where they are then, and go on with that time till the next day at noon, when they determine their new position, and change the clocks to the new time.

Of course, the time is really changing gradually all the while as the vessel moves onward; but, as they can not conveniently make the clocks keep pace with the change, and as, moreover, they do not, during the interval, determine their position, they let them go on until the new position is determined on the following day, and then move them forward or set them back all at once by a leap, as it were, to the new time.

But when they make the land, as they call it—that is, come in sight of it—they, of course, know precisely where they are, and can adopt the time of the place at once, if they choose.

Now England not being very wide from east to west, the difference of time in the different portions of it and of the adjacent waters is not very great, and it is found convenient for many purposes to use Greenwich time—that is, the time of the great central observatory at Greenwich, near London—in every part of the kingdom; and thus it happens that ships, on approaching the land—often, it seems, as soon as they come in sight of the shore—set their clocks at once to Greenwich time.

John did not know this, but as soon as the major made the remark referred to in the last chapter, he understood at once what he meant. Immediately after tea he went down into his state-room and looked at the map to ascertain how many degrees of longitude there were between the meridian of Greenwich and the position of the ship, as near as he could determine it by estimate, that day at noon. He found the distance was twelve or fifteen degrees.

"It must make a difference of nearly an hour," he said to himself.

He knew that the proportion was one hour for every fifteen degrees. For, there being three hundred and sixty degrees in the whole circumference of the earth, and twenty-four hours in the day, a simple process of division will show that the sun must pass over fifteen degrees every hour.

"So I must look out for the first bell," he said to himself, "at half past six by my watch to-morrow morning, instead of half past seven."

He accordingly went at once up to the saloon to inform Louise.

"Why—are we going to have the breakfast earlier?" asked Louise.

"We are going by a different time," said John. "The clocks are going now by the time of the place we were at to-day at noon, but as soon as we get into English waters we shall go by a jump to English time."

Louise looked puzzled. She had heard of "jumping into next week," but whether this phrase of jumping to English time was a joke like that, or what it was, she could not tell.

"I don't understand it very well," said she; "but never mind, I'll be ready."

Accordingly, the next morning, John rose and dressed himself when it was only six by his watch. When it was near half past six, he made his way through several long corridors to the door of Louise's state-room. He had not been there but a few minutes when the door was slowly opened—a little crack, and he saw Louise's eyes peeping out.

"John," said a gentle voice, in a whisper, "are you there?"

"Yes," said John; "all ready."

"Has the first bell rung?"

"Not yet," said John; "but I expect it every minute."

"Then I must wait a little," said Louise, and she shut the door. In a very few minutes the bell rang, and then Louise immediately came out, and she and John went up to the deck.

They found a considerable number of the girls and boys assembling there, though several of them, not understanding about the change of time, were still asleep in their berths.

The air was mild and balmy, the decks were dry, and, more than all the rest, the land was in full view. They were all so much interested in looking at the land that it was some time before they began their play. When at length they were ready to begin, there were enough for an excellent game, and an excellent game they had.

All this time Lionel lay snug in his berth. He heard the first bell, it is true, and aroused himself enough to look at his watch, but, finding that it was only about half past six, he concluded that it was some other bell, and lay down and went to sleep again. At length he was aroused by the second bell, and, dressing himself hastily, he ran along the passage-ways to the state-room of Louise. He knocked gently at the door. Louise's mother opened it. He asked whether Miss Louise was ready.

"Oh, she has gone up on deck long ago," said the lady.

Lionel turned away and hurried back along the passage-ways to go on deck, saying, "It can't be long ago, certainly, for it is not five minutes since the bell rang."

To his utter astonishment, as soon as he reached the head of the stairs leading to the saloon, he found the people all going in to breakfast—groups of girls and boys here and there among them, their faces flushed and beaming with excitement and pleasure.

"What does this mean?" said he to one of the stewards, who was carrying in a great urn filled with coffee; "it is not breakfast-time—it is only half past seven."

"Ah! we are on Greenwich time now," said the steward. So saying, he pressed on, and was lost in the crowd.

It is very true, as Lawrence said, that it is best for us to learn all we can, for there is no foreseeing in how many ways knowledge of any kind may prove to be of use to us. Who would have thought that the enjoyment of an hour of play, and the possession of a charming partner in it, could have depended upon a boy's understanding the relation between difference of longitude and difference of time!

CHAPTER XXXI.

END OF THE VOYAGE.

It was the land forming the southwestern coast of Ireland that first came in sight. It appeared in the horizon like a low cloud, within an hour of the expected time, and precisely in the expected direction, so accurate had been the guidance of the steamer across the pathless waste of waters.

For many hours the passengers sat upon the decks watching the promontories, and cliffs, and light-houses that came successively into view as they sailed swiftly along the coast. The air was mild and balmy, although the region is quite far to the north. The warmth made it very agreeable to be on deck, and it was interesting to reflect that a considerable portion of it had descended from the sun in the tropics months before, and had been brought to the northward in the waters of the Gulf Stream.

It is curious to think how very little heat there is developed on the surface of the earth which we can not trace very readily, though often indirectly, to the sun. All that heat that comes from the combustion of wood and coal—in the fires in our houses, the furnaces of the manufactories, and that which, acting under the boilers of steam-engines, propels ships at sea and trains on land—all comes, as we have already seen, from the sun; for this heat is only the liberation of that stored up in the vegetable organization by the sun while the plant from which the fuel was derived was growing. All the force exerted by men and animals, as was shown in the case of the gulls, comes in the same way, namely, from the reoxydation within the system of substances *deoxydized* by the action of the sun in the leaves of the plants which produced the fruit or the grain which—either directly, or through the flesh of animals in which the deoxydized substances were preserved—served them for food. Thus the food which an animal consumes is really the fuel which drives his mental and physical machinery, for the force is deduced from it in the same way as from fuel, namely, by the reoxydizing of elements which had previously been deoxydized by the power of the sun.

In the same manner, all the heat that is produced by friction comes originally from the sun, for the force which produces the friction is derived from that source. A boy strikes fire with a flint and steel. The spark is a spark of light and heat from the sun, for the friction which produces the heat is an expenditure of force—that is, it is a force converted into heat, and that force comes from the muscles of the boy's arm, being produced there, as has been abundantly proved, by a process very analogous to that of the combustion which evolves force for impelling the steam-engine; and the store of heat which is thus brought out into action was contained in the food which he ate—perhaps that morning—in which food the force was originally stored by the action of the sun.

Even the heat developed when metals are burned comes from the sun, as, for example, in the case of iron, which has been already described, and in that of other metals which can also be burned, though in some cases peculiar precautions have to be taken to facilitate the continued access of oxygen to it. Zinc, for instance, when made incandescent, burns at the surface, but it soon covers itself with a film which shuts off the oxygen of the air from the metal below. But if, while incandescent, it is poured out into the air, it burns continuously in a very splendid manner.

COMBUSTION OF ZINC.

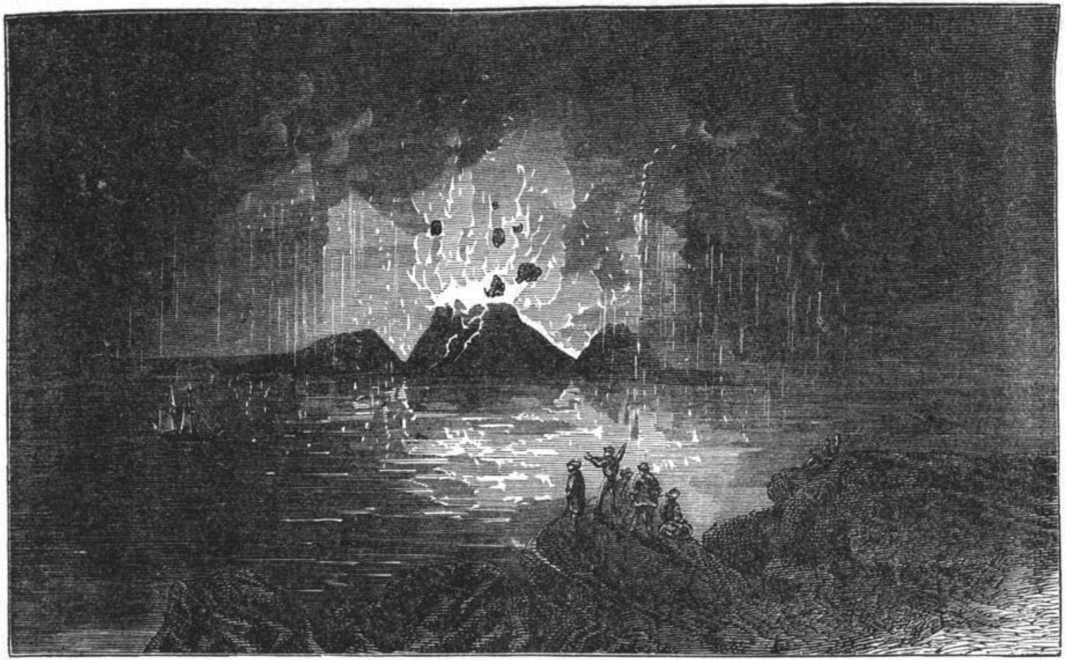
In all these cases, even those of burning metals, the heat developed may be traced back to the sun; for the metal was found in the earth already combined with oxygen, and was separated from it by artificial means, the effective agency in which was heat derived from the combustion of wood or coal; so that, sooner or later, wherever we see heat or force in action upon the earth, if we trace it back to its origin, we come to the sun.

There are, however, some exceptions. There is heat in the interior of the earth which we can not, at present at least, connect with that origin. As we descend into the interior of the earth, as, for instance, in mines, we find a gradual, but very regular increase of temperature. This heat ultimately becomes very great, as we know from the heat of springs of water which come up sometimes from great depths, and still more conclusively from the eruptions of volcanoes. The force and violence of these eruptions are probably caused by the expansive force of steam, produced from water which insinuates itself to the heated region. But the heat itself, although, perhaps, were it not for the intervention of water, it would remain constantly in a state of quiescence and repose, must be exceedingly great, both in quantity and intensity. These eruptions often take place from beneath the sea.

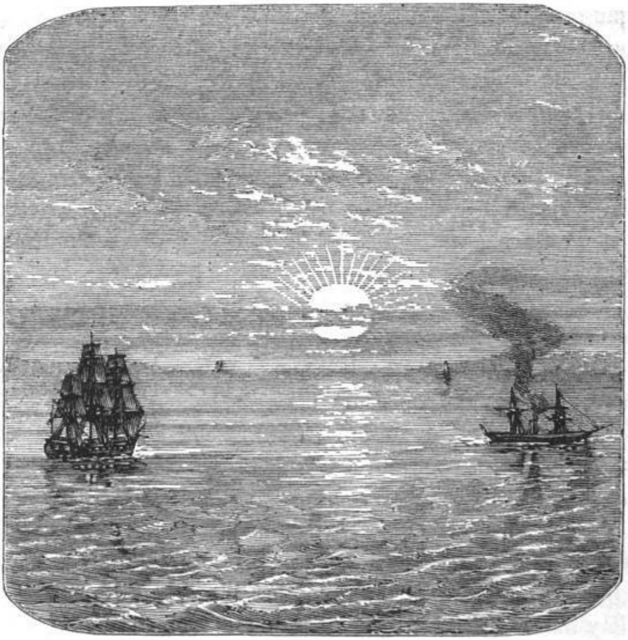
Lawrence and his friend Miss Almira were seated together on the deck conversing on these and similar subjects as the steamer went on up the Channel on her approach toward Queenstown, where she was to stop to land the mails and such passengers as wished to land in Ireland. Lawrence opened a book which he had been reading, and showed Almira a picture which he said afforded a good illustration of what he had been saying. It was a picture of a ship under full sail, which was proceeding on its way under the influence of a gentle wind which filled its sails, and also of a small steamer near, which was going on its way impelled by the power of its engine.

"Here is an illustration," said Lawrence, "of what I have been saying. The sun, by its heat, produced the wind which is propelling the ship, and he also, ages ago, laid up in that ancient vegetation the force which the coal in the steamer is now rendering back for the working of her engine. Thus the sun, in going to his rest, leaves his agents, the wind and the fire, to go on with the performance of their duty while he is gone, in the exercise of strength which he has himself provided for them."

Almira seemed much interested in this train of thought, but, just at this moment happening to turn her head so as to look forward, she saw a small steamer directly before them. The steamer was not moving, but was blowing off



VOLCANIC SUBMARINE EXPLOSION (Volcano of Santorin).



THE SUN AND HIS WORK.

her steam, and she stood directly across the ship's bows, at the distance of about a quarter of a mile.

"What can that steamer mean?" said Almira. "We shall run over her if she does not get out of the way."

"That must be the Queenstown tug," said Lawrence; "she is waiting for us."

"Oh! then I must go below and get ready to land," said Almira; "we are going to land at Queenstown."

Lawrence was quite surprised, and a good deal disappointed to hear this, as he had hoped that Almira's party were going onward to Liverpool, and that he should have an opportunity to call and see her at their hotel. Almira rose, and Lawrence accompanied her to the head of the gangway stairs, expressing his regret that he was to see her no more. She said that she hoped to meet him again in London, or Paris, or at some other place during their tour, and that, at any rate, she hoped he would call and see her in New York on his return to America.

"Do you live in New York?" asked Lawrence, somewhat surprised.

"Yes," said she; "and I will give you my card, with the address, before I leave."

So saying, she went down the gangway to find her father and mother.

In the mean time the steamer continued to advance toward the tug, and soon began to turn off toward the right. The tug, too, began to move forward, and the steamer, taking a grand sweep, and the tug advancing to accompany her, they were soon moving together in nearly parallel directions, but gradually drawing nearer to each other. When they came pretty near they both stopped their engines, but continued moving on under the impulse which they had acquired. The steam-valves were opened, for it was necessary that the steam, since its force was no longer expended in driving the machinery, should be allowed to escape into the air. It formed trumpets of the escape-pipes, and filled the air with such a loud and incessant roar that no other sound could be heard.

There was a great state of excitement and confusion every where on board. The passengers thronged all those portions of the decks that were on the side toward the tug. A vast pile of trunks and baggage had been accumulated near the place for the gangway-plank, where an opening had been made in the bulwarks. Stewards were continually coming with more trunks to add to the accumulation. The passengers who were to land, and those who were to remain, were bidding each other good-by—some by shaking hands with each other in the crowd, and some by exchanging nods and throwing kisses between the upper deck and the lower. The tremendous roar of the steam prevented any thing from being heard.

In the midst of this scene of confusion and noise Lawrence found Almira, and she introduced him to her father and mother, though he could not hear the names, if, indeed, she mentioned the names at all. She also took out a card from a pretty little card-case and gave it to him. It was too dark to see what was upon it, so Lawrence put it in his portmonnaie without attempting to read the name.

In the mean time the tug had been brought up to the side of the steamer and secured, the plank had been laid, and a long line of men were passing over it loaded with bags, trunks, boxes, and every other species of baggage. When this work was completed, the passengers who were to land at Queenstown began to pass down to the deck of the tug. When they were all on board, the little steamer seemed full to overflowing, all the space that was left by the heaps of baggage being filled with passengers—some standing, others seated, some on benches, and some on trunks and baggage—all, however, looking up toward the ship, as the tug moved away, and waving their handkerchiefs in response to the farewell wavings of those on board.

The roaring of the steam in the steam-pipes was now suddenly stopped, and the great steamer began to move forward again on her way, while the tug was lost to view in the obscurity.

The next morning Lawrence and his party landed at Liverpool, and that very afternoon Lawrence went out with the boys to buy their little compasses. He found a kind of ivory pencil-case, with a compass at the upper end of it, and a thermometer at the side.

"Oh, what a cunning little thermometer!" said Flippy, when he saw these pencils. "That is the most splendid pencil-case I ever saw."

"How should you like them for your compasses, boys?" asked Lawrence; "you see there is a compass in the top."

"But that would be more than the bargain," said John. "It was only a compass that you promised, and there is a thermometer here too."

"Oh, never mind," said Flippy; "give us one of these pencils. I'd a great deal rather have a thermometer too."

"And then there is the pencil besides," said John.

"No matter," said Flippy; "that will be all the handier. We can write with our pencil, and tell the points of the compass, and see how warm it is, all in one."

"Very well," said Lawrence, "you shall have them. You were both very good boys all the voyage, and it made the time pass a great deal more pleasantly to me having you on board, and having an opportunity to teach you something. There is nothing that I like better than to teach boys that *like to learn.*"

THE END.

THE ALARM OF FIRE.

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