WHAT TIME IS IT?

M. ILIN

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by a spring? Will your
water as on land? And
heir clocks and watches?
answers to these and many
other questions. And you will begin to realize that telling time is a pretty complicated process after all.

* * * * *

ADMUS BOOKS

WHAT TIME IS IT?

The Story of Clocks

M. ILIN

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Illustrated by
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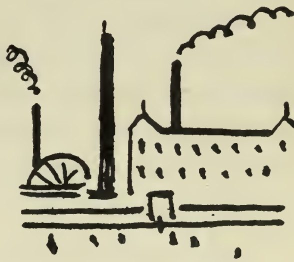
PART ONE

"The rooster beats his noisy wings
And meets the day with song."
Zhukovski—"Svetlana."

What the World Would Be Like Without Clocks

How much those two little hands mean to us—those two little hands that run round and round in a circle apparently never getting anywhere.

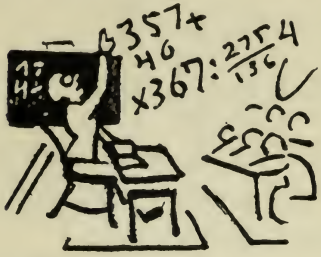


Imagine what to-morrow would be like if all the clocks and watches in the world were suddenly broken all at once! What confusion there would be!

There would be wrecks on the railroads, for you govern traffic with schedules, and schedules depend upon timepieces.

Ships might lose their way at sea for a captain tells where his ship is by his timepiece.

In the big factories work would be disorganized, for the machines in a big factory work by schedule. The articles to be manufactured move in an unbroken stream from one work bench to the next, from one workman to the next. The whole factory works like one huge machine made up of hundreds of machines. And all these big powerful machines are governed by a tiny little machine which is carried about in the pocket—a watch. If the watch should stop, one workbench might be ahead, another behind, with its work. And in a very short space of time the system of the whole big factory would go to pieces and come to a standstill.



And in school? The mathematics teacher would get so interested in his subject that he might keep you beyond the regular time.

If you were planning to go to the theatre in the evening you might get there too early and find your companions in misfortune standing there waiting in front of closed doors. Or you might get there just in time to have the pleasure of seeing the audience fighting to get their coats and hats at the end of the show.

Or suppose you have decided that it is better to spend the evening at home and have invited some guests. You wait for them an hour, two hours, three hours, it seems to you. The fire in the samovar, the tea machine, has gone out long ago. You can hardly keep your eyes open. Finally you go to bed convinced that your company is not coming. No one goes calling at midnight. But in a few minutes there is a great hullabaloo and knocking at the door. Your guests have arrived. According to their reckoning it is about ten o'clock, not a minute later.

You could tell many a story—both funny ones and sad ones—about what would happen if there were no clocks in the world.

Yet there really was a time when there were no clocks of any kind in the world—not a single one—neither the kind that are run by pendulums, nor the kind that are run by springs. But people couldn't get along without dividing the time and they managed somehow to do it. What did they measure it with?

The Antique Shop

I am sure that before you began to read this book you looked at all the pictures—from the beginning to the end. We always do that to see whether the book is going to be interesting or not.

I don't know what you will think about the book, but I am sure that you must have been not a little puzzled by the pictures. What in the world are all those things which at first glance seem to have no connection with one another? They look as if they had been gathered up hap-hazard like treasures in an antique shop. On one page the staff of an Indian Brahmin all carved over with ancient characters. On the next a bronze bell, green with age, embossed with images of saints. Here, an old book with clasps and a thick leather binding like nothing one ever sees on books nowadays. The binding is full of holes, like nail holes. This is the work of rats—rats who died a long, long time ago.

Further on is an oil lamp—not in the least like the kerosene lamps we have to-day. It has no glass about it and there is no burner. Its reed wick smokes and covers the walls with a web of black soot.

Next to it is a Chinese knick-knack like a little boat, with a dragon's head. A wax candle, divided by lines into twenty-four parts. There are two cupids standing at the base of a column. One of them is crying, and the other one is pointing with his little staff at something written on the column.

And last of all, among all this old rubbish, long untouched by any human hand, there is a rooster—a real live rooster, flapping its wings and crowing:

"Cock-a-doodle-doo!"

What does all this mean? Why are there pictures of all these things in a book called "What Time Is It?"

Lamp, dragon, staff, book, candle—they are all clocks which told people the time when there were no real clocks with springs or pendulums.

The Story of Brother Augustin

But I doubt whether the puzzling pictures in the book seem any less puzzling to you after this explanation.

Staff, Book, Lamp—how can they be clocks?

That's just the point. There are so many different ways of measuring time. Anything that lasts for a certain length of time may be used to measure time. Just as anything that has length may be used to measure length.

Brother Augustin's Psalter

It takes you a certain length of time to read this page. That is, you could measure time by the number of pages you have read. You could say, for instance, that you will go to sleep in twenty-three pages, or that your brother came into the room two pages ago.

That's the explanation of one of the puzzling pictures. The thick book with the rat-eaten binding is a psalter. This prayer book of psalms belonged to Brother Augustin, a Benedictine monk. This monk was the bell-ringer in his monastery. Every night, three hours after midnight, he had to ring the bell to wake the brothers for morning service. But how was he to know the time at night when there was no clock? For he lived a thousand years ago when there were no clocks at all.

Brother Augustin had a very simple way of telling the time. In the evening he would begin to read his psalms and when he got to the words: "To the leader of the chorus of Idifumov, Psalm of Asaphs"—he would run to the belfry.

True, he sinned once—went to sleep over his book. And when he woke up the sun was already high in the sky. He certainly caught it for that from Friar Desiderius, the Head of the Monastery.

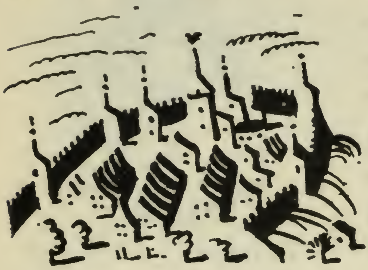
You can see that a book is not an accurate timepiece. For instance, you read fast—twenty pages an hour. But your brother can't get through two in that time. You'll have one time and he another. But time ought to be the same for everybody.

And that's why of all the thousands of ways of telling time there are only a very few good ones.

The Clock in the Sky

That's not all there is to the story of Brother Augustin. Not only the monks got up at the sound of his bell. It also roused the citizens of the little town near which the monastery stood.

And on this morning I am telling you about the weavers and dyers and wool merchants, the peddlers who sold buttons and rosaries and the shoemakers who lived near the monastery never did hear the sound of the bell. When they were finally wakened by the bright rays of the sun, some of them thought that a miracle had been wrought—that the sun had risen in the middle of the night. But when they were really wide awake they realised that the sun was more to be trusted than Brother Augustin—because the sun doesn't drink or eat too much, a weakness from which Brother Augustin was not altogether free.



People have always regarded the sun as the most trustworthy of clocks. Long before the day was divided into twenty-four hours people told time by the sun. To-day, we still, instead of saying "at such and such a time," say "at day-break," "at mid-day" (that is when the sun is at the highest point in the heavens), "at sunset," "at twilight," "after sunset."

In cities no one ever thinks of telling time nowadays by the sun. But in the country people often

The Sun as a Sky Clock

use the sky clock for want of a better. It isn't necessary for a farmer to know the time as exactly as it is for the person who lives in the city. He doesn't have to go to his work at an exact moment. His schedule is simple and easy: work from sunrise to sunset. That's all there is to it.

Not so in a grain factory, which is one way of describing our big Russian farms owned by the government and worked by the people who live on it, that is a sovkhoz or a kolkhoz. There the work is carried on as in any other factory, according to schedule. There you can't get along without clocks.

It's no wonder that long ago, when there were no cities and factories, people didn't feel the need of measuring time accurately.

Measuring a Shadow

But when cities sprang up here and there, when gay markets and bazaars appeared, when hammers began to resound in the workshops of the artisans and merchants' caravans stretched in long lines along the highways—then people began to find the sky clock not sufficiently accurate. For you can't possibly tell exactly, just by looking, how far the sun has travelled in the sky since it rose. How can we measure this distance more accurately?

The simplest way would be to measure it by steps as people were in the habit of measuring distances on the ground. In those days a step was the measure of distance just as metres or yards are with us. But the sky is not the earth and you can't possibly climb up there.

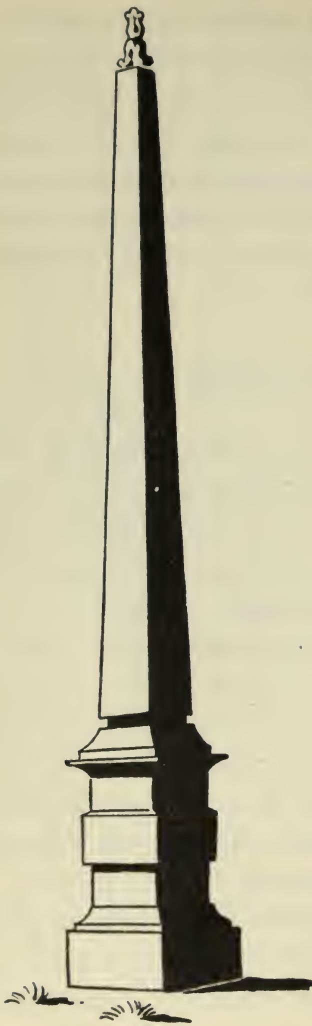
Fortunately, there have always been people in the world who could do what seemed to other people impossible. Just as there are people in our time who have learned to fly through the air, to sail under the water, to talk to each other when they are in different cities—so in olden times people solved another insoluble problem—they learned to measure time by steps.

How People Measured Time by Steps

In a comedy written by a Greek writer, Aristophanes, twenty-three hundred years ago, an Athenian woman, Praxagora, says to her husband, Blephiros: "When the shadow is ten steps long, anoint yourself with perfume and come to supper."

Notice what a strange way people had of making their toilets in those days. In place of washing off the dirt they anointed themselves with all kinds of perfumed ointments and oils. The dirt didn't matter, so long as it didn't show and smelled nice. But that's not the point here. What is the meaning of the expression "ten steps long"?

Apparently not far from the house where Praxagora and Blephiros lived, there stood a pillar or monument. On a sunny day—and in Greece nearly



A Gnomon

all the days were sunny —this monument cast a shadow. To know the time of day people stepped off this shadow as they passed. In the morning it was longer, at noon it was at its very shortest, and in the evening it grew longer again.

There's the answer to your question as to how people measured time by steps. As usual the answer seems just as simple as the riddle seems difficult.

The Indian Fakir's Trick

A pillar which was used as a clock was called a *gnomon*. You can see that a *gnomon* was a very inconvenient clock. Not only did it show the time only on sunny days, and then very inaccurately, but you couldn't take it with you on a journey. And a clock is very necessary when you are travelling.

The Indian fakirs—those jugglers whom everybody has heard about—solved the problem in a simple and clever way. They made a clock of an ordinary walking stick. A fakir who was going to make

An Indian Fakir with His Watch

the long journey to the holy city of Benares took with him a special kind of walking stick.

This stick was not round, like our canes, but octagonal. At the top, on each one of the sides, a little hole was drilled, into which fitted a short peg.

When the fakir wanted to know the time of day he lifted up his cane by a string attached to the top. The shadow which the peg cast on the side of the stick, showed him what time it was. He didn't have

An Indian Portable Watch

to measure the length of the shadow every time, because there were little marks cut on the sides telling the hours.

But why so many sides? It would seem that one ought to be enough. The reason is that at different times of the year the path of the sun is different. So the shadow, which depends on the sun, doesn't act the same way in summer as in winter. In summer the sun goes higher up into the sky than in winter. So the shadow cast at noon-time is shorter in summer than in winter.

That's why the cane had so many sides. Each side was measured out for one season of the year, and wasn't good for any other. Suppose it is the beginning of October, the fakir puts the peg into the hole in the side marked "Ariman," the name of the month which corresponded to the time from the middle of our September to the middle of October.

You can easily make a clock like that for yourself. Four sides are enough—for the four months which you spend in the country. In the winter one doesn't need a cane, and also the sun doesn't shine very much of the time.

It will take you four days to make such a clock, one for each month. In the morning when you get up, say at seven o'clock, insert the peg in one of the sides, and make a mark at the place where the shadow ends. At eight o'clock do the same thing, and so on until sunset.

Clocks Which Had Faces But Which Lacked Hands

In the days of our old friends Praxagora and Blephiros, you could already find here and there in Greece a new kind of clock which was much more convenient. They say that this new invention came to Greece from Babylon, a city which had long been famous for its learned men.

Babylon was at that time one of the largest cities in the world. The streets were busy and noisy. Companies of soldiers went by, marching in perfect order. Merchants sold sweet-smelling ointments, candies, and ornaments. Dandies with curled beards, with rings on their fingers, carrying slender, gold-headed canes in their hands, strolled about. Above this gay oriental crowd towered tall, many-storied buildings. Such was Babylon some twenty-five hundred years ago. It is not to be wondered at that science too flourished in that rich and populous city.

The Greeks learned a great deal from the Babylonians, just as in the time of Peter the Great the Russians learned from the Germans, Dutch, and Swedes. The Babylonians taught the Greeks to divide time into equal periods—hours. From the Greeks this division passed over to the other nations of Europe, in the course of many, many years. It was from the Babylonians, so they say, that the Greeks learned how to make a new kind of clock—the first clock with a face or dial plate. True, this clock lacked one little thing—hands.

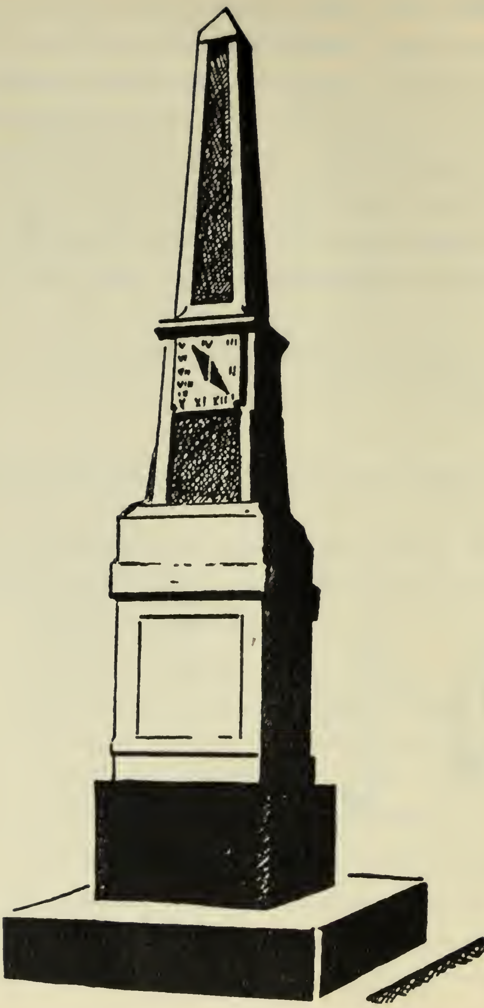
Hands? you say. But how could there be a clock without hands? To convince yourself that there are such clocks you don't have to go so far as Asia. There are many handless clocks in Soviet Russia. Here and there along the old road leading from Leningrad to Moscow stone mile posts are still standing, placed there in the time of Catherine II. There are also some in Leningrad, along International Prospect (near Fontanka, and at 7 Red Army Street) and in Children's Village, near the Orlovski gate.

On the stone in Children's Village, there is written on one side:

From Saint Petersbourg Twenty-two Versts

On the other side there is a flagstone with a triangular iron plate set upright in the middle of it, and Roman figures marked round the edge. The Roman figures stand for the hours. The shadow of the iron plate takes the place of the hands. As the sun mounts into the sky the shadow moves, like the hands of a clock, and shows the time of day.

This is a sundial, such as were in use in ancient Babylon.



A Sun-dial Clock

When a traveller in old Russia passed one of these mile posts he could look out of the window of his carriage and see how many versts he had yet to go and how much time he had spent on the way so far.

Sundials were certainly better clocks than the gnomon or the fakir's cane. They were much more accurate and reliable. Nevertheless, they were far from the clocks we have to-day. You'd hardly be satisfied with your clock if it went only when the sun shone and stopped at night and in bad weather. And that's just what sundials did. As they used to say in those old days, they were "day clocks."

Night clocks, too, were invented a long, long time ago, apparently at about the same time as sundials.

Ivan Ivanitch's and Ivan Petrovitch's Little Talk

Two old friends, Ivan Ivanitch and Ivan Petrovitch have not seen each other for ten years. One day they unexpectedly meet in the street.

What do you suppose Ivan Ivanitch would say? And what would Ivan Petrovitch reply?

I haven't a doubt but that Ivan Ivanitch exclaimed, between two kisses:

"How much water has flowed away, my dear old friend Ivan Petrovitch!"

And Ivan Petrovitch replied:

"Quite a little, Ivan Ivanitch, quite a little."

But do these two know what this old expression means? What water are they talking about? Where has it flowed to and where did it come from?

I think that our two friends would be completely at a loss for any kind of explanation of this.

The expression which Ivan Ivanitch used has long since lost all its meaning and people repeat it like parrots, never thinking about what it means.

A Samovar

But this is what it means: long, long ago people discovered that time could be measured by means of water. If you fill a samovar with water and then open the faucet the water runs out. Suppose it takes it an hour. If, without changing the faucet, we again pour into the samovar just as much water as before, it will run out in just the same time—not in half an hour and not in an hour and a half, but in exactly one hour.

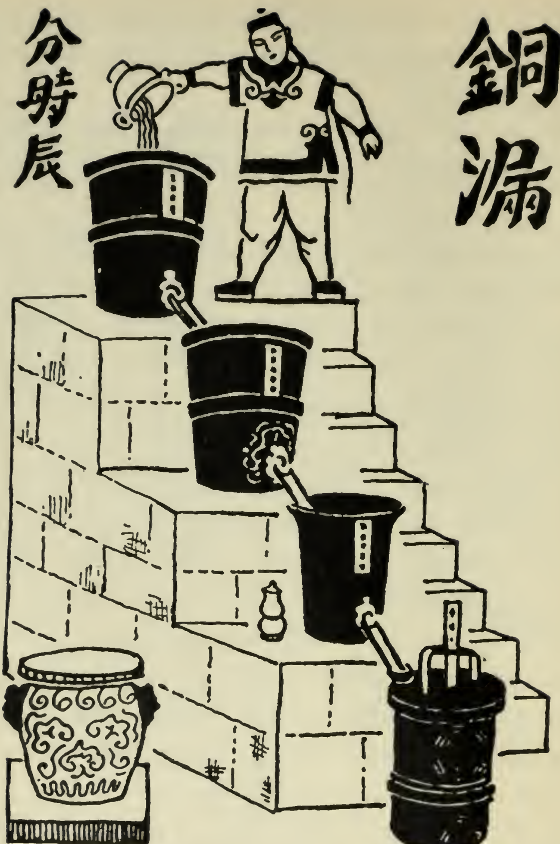
That is, this samovar could be used as a clock. All you would have to do would be to fill it up again every time it ran out.

Such clocks were in use in Babylon twenty-five hundred years ago. Only they didn't put the water into a samovar, of course, for there weren't any samovars, but into a tall, narrow vessel with a hole near the bottom. Special people were appointed to take care of the clock and at sunrise they filled the vessel with water. When the water had all run out they shouted out an announcement of this fact to the inhabitants of the city. Then they filled the vessel up again. They did this six times per day.

Water clocks were very inconvenient. They were a great deal of trouble. However, they did tell time in bad weather and at night. That's why they used to call them "night clocks" to distinguish them from the day clocks or sundials.

Not so very long ago there were still some of these old-fashioned water clocks to be seen in China.

Four big copper kettles were arranged, one below the other, on the steps of a stone staircase. The water ran from one vessel down into the next. Every two



A Chinese Water Clock

hours (or "ke" as the Chinese say) the guard hung out a little sign board showing what "ke" was passing.

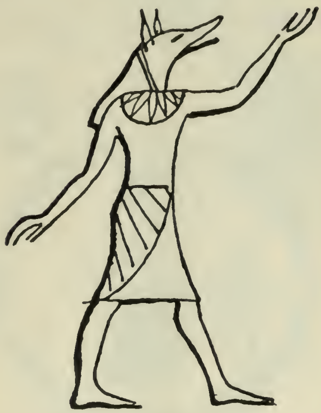
It is easy to understand why they arranged the kettles in this way. The guard had to fill only the upper kettle, and the rest were filled automatically one after the other. I do not know whether they are still using these water clocks to-day, when all kinds of machines, the radio, and aeroplanes have reached China. But twenty-five years ago such clocks were still in use, so they say.

A Milk Clock

Milk Clocks

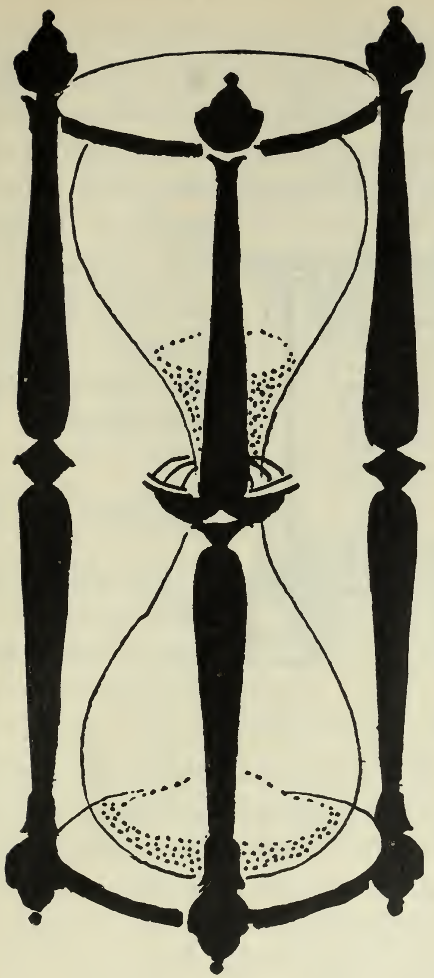
Milk clocks? What kind of nonsense is this? There are milk pigs and milk calves, there is milk chocolate and there are milk teeth. But what in the world is a milk clock?

I read about these milk clocks in an old book about the art of clock-making. In this book it tells how in ancient Egypt there stood on one of the islands of the Nile a temple to the God Osiris. In the middle of the temple were three hundred and sixty vessels with holes in the bottom. A special priest was attached to each vessel, so there were three hundred and sixty priests. Every day one priest filled his vessel with milk and the milk emptied out in exactly twenty-four hours. Then another priest filled up the next vessel, and so forth all the year round.



It is hard for us to understand why the Egyptians needed so many "milk clocks," why the Pharaohs didn't think of cutting down the number of employees in Osiris' temple. It must have cost quite a little to feed three hundred and sixty men whose only occupation was to pour milk into empty vessels.

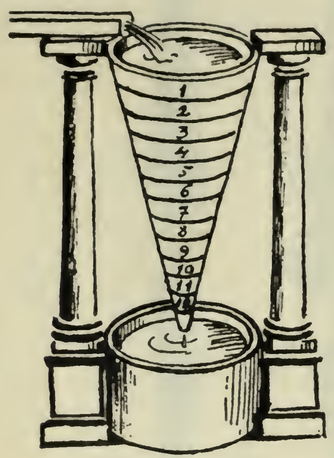
Other things besides milk were used in place of water in such "water" clocks. There were sand clocks, too. We have them to-day. To wind these clocks you merely have to turn them over. These clocks are convenient for measuring small intervals



A Sand Clock

of time: three—five—ten minutes. Some housekeepers use them to tell how long to boil an egg.

It used to be thought, in ancient times, that the sand for these clocks had to be prepared in a special way. They said that the very best sand was that made of marble boiled nine times in wine. At each boiling the scum was skimmed off and at the end the sand was dried in the sunshine.

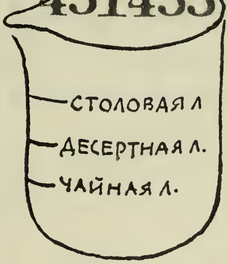


A Funnel Water Clock

Clocks and Potions

The first and simplest form of water clock was a vessel with a hole in the bottom from which the water trickled out drop by drop. This was soon changed and improved. The first thing was to plan things so that the vessel would have to be filled as rarely as possible. People soon realised that instead of a small vessel calculated for one hour's supply they could use a bigger one with a whole day's supply. And in order to measure not only days but also hours the vessel was divided by little lines into twenty-four parts. Now the water's level itself showed the time of day. All one had to do was to look to see how far down the water had gone.

You have probably seen the little glasses with divisions marked on them which are used to measure out medicines for sick people. There are three little lines on the side of the glass: on the lowest is written "teaspoon," on the middle one "dessert spoon" and on the upper one "table spoon."



The water clock vessel was marked in the same way. Only instead of three lines there were twelve or twenty-four. And they were not for measuring medicine but for measuring time.

But there was one inconvenience with this method. Water does not always pour out of a vessel at an even speed. At first when there is still a lot of water it runs out faster than it does later when the quantity is less. It is easy to see why this is so. The higher the water level the greater the pressure, and the greater the pressure the faster the water will run out. The same thing is true in a water system: the higher the tank from which the water comes the faster the water runs in the pipes.

So, at first, more water ran out during one hour than later on. The water level at first goes down very fast, later more slowly. So the lines had to be drawn at unequal distances from each other: the higher ones further apart, the lower ones close together.

There was another better way: to make the vessel in the shape of a funnel. If the funnel was properly made the lines could then be put at equal distances from each other.

You can see that there would be more water between two lines higher up on the funnel than between two lower down, which is just as it should be. For during the first hour when there is more water in the vessel more of it flows out than during the next hour.

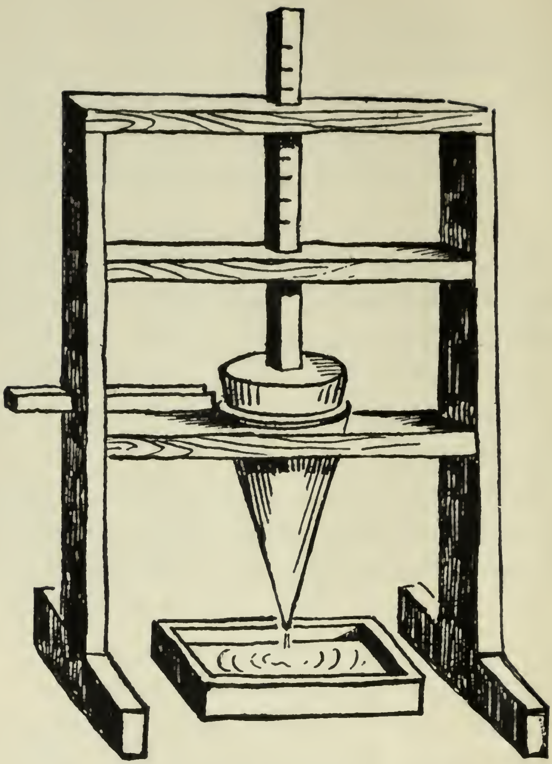
"Big" and "Little" Hours or *Long and Short Hours*

Everybody knows what I mean if I say that it took me just one hour to write this chapter. But in ancient times, some two thousand years ago, people would have asked me what kind of hour I meant, a big or a little hour.

We know that the ancient Egyptians, Greeks, and Romans divided the day into twenty-four hours, as we do, but not in exactly the same way. First of all they divided the twenty-four hours into day and night. Day was from sunrise to sunset, night from sunset to sunrise. Then they divided day and night into twelve hours each. But days and nights are not of equal length. So in the summer time the day hours were longer and the night hours shorter. In the winter time the day hours were shorter and the night hours longer. In some parts of Egypt a day hour was in summer equal to an hour and ten minutes of our time, and a day hour in winter was only fifty minutes long.

In the northern part of our country where the sun is visible for only a short time every day during the winter, a winter day hour would be only about forty minutes long. This would be a little hour. While a night hour would not be an hour, but an hour and twenty minutes—a big hour.

So water clocks built for summer time weren't right for winter time, and vice versa. This had to be corrected somehow. In winter the day is shorter than in summer. That is, in winter there would have to be less water in the funnel so that it would empty more quickly. For instance, if two pitcherfuls



A Perfected Water Clock

were needed in the summer, in winter one would be enough.

But it was not so easy as it seems to solve this problem. For, you see, the funnel had to be filled to the top line in both winter and summer. And if you put in only one pitcherful instead of two the funnel will be only half full. What shall we do? How shall we manage so that the wolves shall be fed and the lambs still safe? So that there shall be less water in the funnel and it shall, nevertheless, be full to the top?

This is what they devised. They made a solid cone, in the shape of the funnel. If this cone is lowered into the funnel, say up to the middle, there will be less free space in the funnel and consequently it will contain less water. That is, in winter the cone will have to be let down and in summer raised up. So as to make it possible for any one to raise and lower the cone, little lines were made on it too, showing to what depth it should be lowered at different times of the year.

You can see that these clocks were more complicated than the earlier ones. If people had only thought of dividing the day into twenty-four hours, as we do, these water clocks would have been much simpler.

A Live Alarm Clock

From Babylon and Egypt, where there were water clocks as far back as we know anything about these countries, the idea was carried to the Greeks, and from them to the Romans. The first water clock in Rome was placed in the market place alongside a sundial. They did this so as to test the correctness of the water clock by the sundial.

Water clocks get out of order very easily—if, for instance, a little dirt gets into the hole through which the water empties. But a sundial, provided the sun is shining, always tells the time honestly and conscientiously.

Sometimes water clocks were to be found in the homes of rich people. Special servants had to fill them with water and see that they were kept in order. But there were very few people so fortunate as to be able to have water clocks of their own. All the rest of the citizens had to be satisfied, as before, with the sun by day and the rooster by night.

When people, tired out by their day's work, were half awakened by a rooster somewhere off at the edge of town, crowing lazily now and then, they would turn over, drowsily, and go happily off to sleep again—knowing that dawn was still a long way off. For it is only in the dead of night that roosters

crow in that way—a single, sleepy crow at rare intervals, what, in olden times, they used to call the rooster's "first crow."

But now he begins to crow more frequently and more briskly. It will soon be dawn. Another day, just like yesterday, will begin.

For thousands of years people were used to their living alarm clocks. Is that, perhaps, why the sound of a rooster crowing in the night awakens in us a vague feeling of anxiety?

The Story of Marcus and Julius

Two thousand-odd years ago people could easily get along without clocks. As the saying went, "The soldier is wakened by the trumpet, the citizen by the cock." And during the day it was easy to tell the time by the sun. But even then there were cases where clocks were considered not a luxury but a necessity. Judges, for instance, couldn't get along without clocks. To keep trials from lasting too long a time every one who wanted to speak was allowed the floor for a certain length of time. And they had to have clocks for this.

Greek and Roman judges used water clocks of the simplest construction. They consisted of a vessel with a hole in the bottom from which the water ran out in approximately a quarter of an hour. The Greek word for water clock is "klepshydra." So when one wanted to say that a speech lasted for an hour he would say that it lasted for four klepshydras.

Once an orator who had talked straight along for five solid hours was finally interrupted by the question:

"If you can talk so long without stopping, how many klepshydras can you keep still?"

The orator didn't know what to answer, and so, amid general laughter, proved that he knew how to keep silent too.

In an old book I read the story of a man whose life was saved by a water clock.

A citizen of Rome was being tried for murder. His name was Marcus. There was only one witness who could save him, his friend Julius. But the trial was drawing to a close and Julius hadn't yet put in an appearance.

"What has happened to him?" thought Marcus. "I wonder if he isn't coming at all."

According to the law the accuser, the accused, and the judge were each allowed to talk for the same length of time. Each one of them could speak for two klepshydras, that is half an hour.

First the accuser spoke. He showed that all the evidence was against Marcus. He should be condemned to death for murder. The accuser finished his speech. The judge then asked Marcus what he had to say in his own defence.

It was hard for Marcus to talk. Terror froze his tongue when he saw how the water was running out of the klepshydra, drop by drop. With every drop his hopes of salvation diminished. And still no Julius.

One klepshydra had already come to an end. The second one was beginning. But then a miracle happened. The drops began to fall more slowly, much more slowly, than before. Marcus took hope again. He purposely dragged out his story. He told about his relatives, how they were all honest people—about his father, his grandfather, his grandmother. He had just begun to talk about his grandmother's cousin, when the accuser happened to notice the clock, and cried out:

"Some one has thrown a pebble into the clock! That's why the prisoner has already talked at least four klepshydras instead of only two!"

Marcus grew pale. But at that very minute the crowd of onlookers parted and Julius made his way through them to the front. Marcus was saved.

Who threw the pebble into the klepshydra?

There's not a word said about this in the book where I read the story about Marcus and Julius. Do you think that it may have been the judge who did it, out of pity for poor Marcus?

The Clock-makers of Alexandria

In the times about which we are talking, some two thousand years ago, Alexandria, in Egypt, was especially famed for making water clocks. It was a rich commercial city. They used to say that you could find everything but snow in Alexandria. It was here, it seems, that the first clock-making works in the world came into existence. The manufacture of clocks, which had hitherto been in the hands of a few learned inventors, passed over into the hands of artisans, master clock-makers. They were called "automataries-klepshydraries." This word, which is not so easy to pronounce, means "makers of automatic water clocks—automatic klepshydras."

What were these automatic, or "self-working," clocks like? For the klepshydras we have been talking about were far from being self-working. They gave plenty of trouble.

About two hundred years before the first clock-makers' shops appeared in Alexandria, there lived in this city an inventor who thought out a new, very ingeniously constructed water clock. His name was Ktesibius. He was the son of a barber. But his father's trade wasn't to his taste. Instead of shaving the beards of the citizens of Alexandria he spent his time studying science, especially mechanics.

He was specially interested in machines whose motive power was water. For at that time they didn't yet know about steam and electric power. The only mechanical motors they had were water and wind. Waterfalls turned the wheels of water mills. Wind made the wings of windmills go round but Ktesibius had an idea. Would it be possible to make a water clock which would work of itself, an automatic water clock?

The clock which Ktesibius made was even more ingenious than ours. For his problem was a far more complicated one. He had to make a clock which would wind itself and which would show the time correctly both summer and winter. You mustn't forget that in those days the length of the hour changed every day. Ktesibius had to take this into account.

The clock which Ktesibius set up in the temple of Arsinoë is shown in the following picture. This is the way it worked: the hours were marked on the column in both Roman and Arabic figures. The Roman figures stood for the night hours, the Arabic for the day hours. An amusing dial, isn't it? Not round, like ours, but perpendicular.

The hand of this clock was a little stick held in the fists of a little winged boy who stood on a tube. This tube automatically moved out of the clock and slowly lifted the boy from the bottom to the very top of the column. The hand—the little stick—moved along with the boy and pointed to the time. Of course it took just twenty-four hours for the boy to go from the bottom to the top of the column. He then fell down to the bottom and again began his slow ascent.

But that's not all there was to it. The hours then were of different lengths at different times of the year. Therefore, there was not merely one dial on the column, but twelve, one for every month of the year. The column turned slowly round on an axis and brought the different sets of figures under the boy's stick one after another.

You can see that this was a very ingenious and elaborate clock. But I think you will not have any trouble in understanding its construction if you will read carefully all that I am going to tell you about it and not forget to look at the pictures which show how it was made on the inside.

On the other side of the column there was another little winged boy who never stopped shedding bitter tears, weeping, apparently, about the time that had gone forever. The water ran into him through a little tube and came out through his eyes in the form of tears. Drop by drop the boy's tears fell to his feet, and ran through a little tube into a small box placed directly under the other boy. In this box there was a float made of cork to which was attached one end of the little tube on which the cupid with the pointer was standing.

As the water rose in the box, the float rose, and with it the cupid with the pointer. When he reached the top of the column and his stick pointed to the figure XII, the water in the box was quickly emptied out through a pipe bent in the shape of an inverted V, the float fell down, and with it the cupid. A new day began and the boy again started on his little journey.

The picture shows the moment when the water is running out of the bent pipe.

We must see how the column was arranged so that it turned round an axis. The water poured out of the bent tube onto a water wheel. This water wheel turned a small cog wheel which was attached to the same axle. The cogs of this wheel were meshed into the cogs of another little wheel and made it also turn. This wheel, in its turn, turned another pinion, and this pinion turned another cog wheel. In this way, by means of four cogged transmissions, the mill wheel turned the axle to which the column was attached.

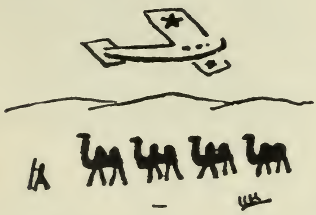
Every twenty-four hours the water poured out from the elbow pipe and turned the mill wheel, and this made the column move a little bit. In the course of a year it made one complete revolution. The next year everything started from the beginning again.

You can see that this clock could keep going indefinitely. All that was needed was a simple arrangement of water pipes. Such a klepshydra certainly had the right to be called automatic.

After Ktesibius, people started to make still more ingenious and complicated clocks. There is one picture of a water clock which, on the outside, looks almost like a clock of to-day. It has a round dial, hands, and even a pendulum. But the pendulum was not weighted, as in our clocks. It was a light one, made of wood, and like the cork float, it floated in a small basin from which the water kept running out all the time. As the water level lowered the float lowered, and thus made the mechanism move.

The Clock of a "Thousand and One Nights"

In the days when the shores of the Mediterranean Sea—Italy, Greece, Egypt—were already populated by cultured people, almost all of Europe was still inhabited by half-wild nomads. The people who at that time lived in what are now France and Germany were not very different from the Mongols of a later date.



But times change. On the Mongol steppes automobile horns now frighten the long-haired camels. High over the old Mongol camps great white birds are flying—Russian aeroplanes flying from the U.S.S.R. to China. It was so in ancient times too. Inventions, customs, ways from the Mediterranean coast slowly penetrated the

North, taking their course into the midst of the "barbarians" or, as we say, the savage tribes.

It was about seven hundred years after the time of Ktesibius before the first klepshydra appeared in France. This was a clock sent by Theodoric, King of Italy, to his neighbour and ally Gondebeau, King of Burgundy.

King Theodoric, who lived in the beautiful town of Ravenna in northern Italy, had a wise and learned councillor called Boetius. Boetius was also a very clever mechanic. By order of the king he constructed a clock which showed not only the time but also the movement of the stars as well.

When Gondebeau, King of Burgundy, who reigned in the city of Lyons, heard of this, he ordered a letter to be written to Theodoric requesting: (1) a sun clock, and (2) a water clock which would show the time and also the movements of the heavenly bodies.

Boetius, at Theodoric's orders, constructed a very wonderful clock which was sent to Lyons with written directions as to how it was to be used. These letters which passed between Theodoric and Gondebeau have been preserved to our time.

For a long time after this water clocks were still considered rare curiosities in France. Now and then some king would be presented with a water clock from Italy or from the Orient where the art of clock making was preserved.

So, in 761, that is one thousand one hundred seventy-one years ago, King Pepin the Short was presented by the Roman pope with a water or "night" clock, as it was then called. But the most

wonderful of all was the clock which the famous Haroun-al-Raschid, about whom so many stories have been written, sent from far-away Bagdad to another famous king, Charlemagne, at Aix.

There have been many stories, songs, and ballads written about both these characters. We have all of us been fascinated by the stories of the "Thousand and One Nights" and remember the caliph who used to disguise himself as a poor man and wander, with his vizier, along the streets of Bagdad.

It was this same Haroun-al-Raschid who sent Charlemagne a water clock which for those times was a miracle of art.

Eginhard, the friend and councillor of Charlemagne, describes this clock as follows:

"Abdallah, ambassador of the Persian king, presented himself to the Emperor together with two monks. The monks, George and Felix, presented Charles with several gifts from the Persian king, among others, a gilded clock, very artfully constructed. A special mechanism, set in motion by water, showed the time. The clock struck the hours. Every hour the required number of little copper balls would fall into a copper basin at the foot of the clock. And every hour one of the twelve doors leading into the inside of the clock opened. At noon from all the twelve doors there rode out twelve little knights, who shut the doors behind them. The clock had many other astounding features never before seen by our Frenchmen."

Fire Clocks and Fire Alarm Clocks

Water clocks were for a long time still a rarity in France and in the other European countries. Three hundred years after Charlemagne one could find, here and there in some rich monasteries or princes' palaces, klepshydras which struck the hours. But

A Candle Clock

most of the monasteries and almost all the population of town and country did without clocks, as before.

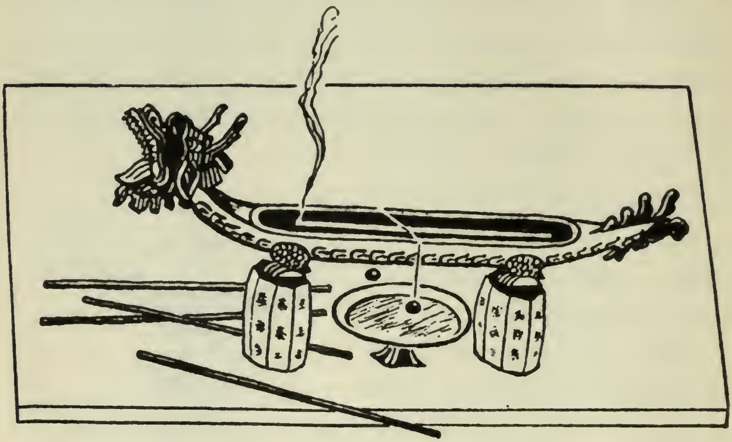
It was hardest of all for the monk to get along without clocks. Eight times a day, every three hours, the monastery bells called them to prayer. After the morning prayer came the prayer of the first church hour (by our time seven, eight, and nine o'clock in the morning). Then came the third hour (by our time ten, eleven, and twelve o'clock noon) and so on all day long.

You can see that the poor bell-ringer had a hard time. He was always looking out from his bell tower to tell the time of day by the sun or stars. And if the sun and stars were not to be seen, he had to measure time in the same way as our old friend the monk Augustin, by the number of psalms he had read through.

There was, it is true, another and better way. That was to measure time by the quantity of oil burned in the lamp or wax in the candle. At one time such fire clocks became so common that the question, "What time is it?" was answered by "one candle" or "two candles." The night was divided into three candles, and to say that it was now "two candles" meant that two thirds of the night had elapsed. They also used oil lamps and candles with divisions marked on them for more accurate measuring of the time.

But the oil lamps of those days burned with an unequal, smoky flame. Candles were not of uniform thickness. So they were not very well suited for measuring time. They were merely tolerated because there were no other clocks—"among the blind a one-eyed man is king." In some monasteries the regulations simply directed the bell ringers to listen to the roosters' crowing at night.

It is said that in China fire alarm clocks are used even now. A rod made of saw-dust and pitch is put into a little boat. Two little copper bells are hung across the boat on a thread. One end of the rod is



A Chinese Fire Alarm Clock

lighted. When the fire reaches the thread it is burned up and the little balls fall with a clang into the metallic plate placed under the little boat.

The citizens of Paris used to arrange their time by the church bells. Shoemakers, upholsterers, cloth makers, galloon makers, would all finish their work at the first bell for vespers. Bakers baked bread till the early morning church service. Carpenters finished their work at the first stroke of the big church bell of Notre Dame.

At eight o'clock on summer evenings and seven in winter, the bells gave the signal: put out the lights. And everybody hurried to put out lamps and candles and go to sleep.

It is interesting to notice that in those days when it was so very hard to reckon time at all, when it was easy to lose track of a whole hour, wise men racked their brains over the question as to how an hour should be divided. One, for instance, proposed to divide an hour in this way—one hour, four quarters, fifteen parts, forty moments, sixty minutes, twenty-two thousand five hundred atoms.

Another didn't agree with him but said that an hour should be divided in this way: one hour, four quarters, forty moments, four hundred eighty ounces, five thousand six hundred forty minutes.

All this nonsense is forgotten long ago. But it was only when clocks with weights and pendulums appeared that it was possible to divide the hour into parts—into minutes and seconds.

PART TWO

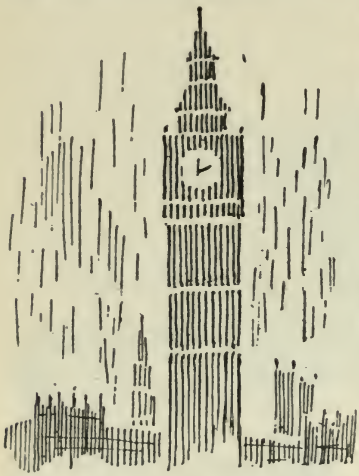
The Plunder of the Crusaders

Who invented clocks with weights? We don't know certainly. But the first clocks of this kind we know about were brought from Palestine by the Crusaders. As in the time of Haroun-al-Raschid, the Arabians were still more educated and advanced in the arts than Europeans.

In the gloomy halls of the knights' castles, whose walls were blackened with the smoke of torches, through which the winds blew as freely as in the open fields outside, luxurious turkish carpets began to appear, and silken hangings, vari-coloured chibouque, curved swords of embossed Damascus steel.

Along with all this oriental luxury clocks with weights were probably brought in by the Crusaders.

At any rate, we know that seven hundred years ago the Sultan Saladin presented his friend the Emperor Frederick II with an ingenious clock with weights. The price of this clock was five thousand ducats—a huge sum for those times.



Big Tom

Fifty years later the first tower clock appeared in Europe, King Edward I ordered a big clock to be placed on Westminster Tower in London, above the House of Parliament. This is a high quadrangular tower, with a sharp pointed cupola at the top. It towers over all the surrounding buildings like a giant among dwarfs.

Three hundred sixty steps led up to Big Tom, as the English called their first clock. For four centuries Big Tom tolled out the hours without a single break. On foggy London days the old tower, like a lighthouse on a foggy sea, sent its hard, metallic signals of alarm out in every direction, seeming to say:

"Time is passing! Hurry, hurry, hurry!"

And perhaps the members of Parliament, sitting down below in their wigs and gowns, laid aside for a moment their goose quill pens and thought about something which is more important than all laws, taxes, and customs duties.

Afterwards Big Tom's place was taken by Big Ben. But we'll tell you about that later on.

Very soon after this, tower clocks began to appear in other European cities too. Charles V, King of France, sent to Germany for the famous clock-maker, Henry de Viek, and ordered him to put a clock on the tower of the royal palace in Paris. The German master worked eight years on the construction of this clock. When it was completed he was given a salary of six sous a day, and living quarters in the clock tower, for looking after the clock, keeping it running and in order.

Within a few years, another master clock-maker, this time a Frenchman, Jean Jouvence, made a clock for one of the King's castles. On it is an inscription reading:

CHARLES THE FIFTH, KING OF FRANCE
SET ME UP WITH THE HELP OF
JEAN JOUVENCE IN THE YEAR
ONE THOUSAND THREE HUNDRED EIGHTY

Jean Jouvence and Henry de Viek—these are the only two names of the clock-makers of those days which have come down to us.

In Russia the first town clock was set up in 1624 in one of the towers of the Kremlin. The Spasskaya tower now stands in the place formerly occupied by this clock tower.

Clock and Well

Lots of us, when we were very young children, used to think that clocks were alive, that it was their own little hearts beating away inside them and if the case was opened we were quite awed by all the movements of the numerous shiny little wheels. It was a regular factory!

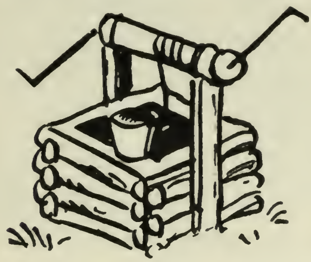
And to think that all this work and hurry is just to move those two lazy little fellows—the hour and minute hands—which at first glance seem not to be moving at all.

Now, in every factory there is some kind of motive power—a steam engine, a Diesel, or something of the sort, which sets all the machinery to work. A clock has to have some kind of engine too, for they are not really alive, you see.

Did you ever see a well which was worked with a windlass? The windlass is the cylindrical shaft round which the rope is wound. One end of the rope is fastened to the windlass and the pail is hung at the other end. If you wind up the windlass by the handle you lift up the pail of water. But let go the handle and the pail you worked so hard to lift up goes down like a shot, unwinding the rope and making the windlass and handle whirl round at a mad rate. You'd better move away a little then or the handle will give you an unceremonious crack.

It is quite likely that the inventor of clocks with weights copied a well windlass. The pail corresponds to the weight and the whirling handle to the hands of the clock. But when the pail is released it flies down like a flash, going faster and faster all the time. The handle turns around so fast that you can't count its revolutions. Now, in a clock the hands must go slowly. Even a second hand doesn't move so very fast and a clock has to measure hours, not seconds. Then, too, the hands must move at an even pace—not like the handle of the windlass which keeps going faster and faster the further down the pail goes.

There you have the difficulty. Some kind of arrangement had to be thought up which would hold back the unwinding of the rope and the falling of



the weights, and would, at the same time, make the windlass unwind at an even pace. There is just such an arrangement in every clock, the regulator, which governs its speed. Clocks run by springs have to have regulators too. If a spring which is wound up tight were suddenly released it would unwind in an instant and the clock would stop immediately. The spring must also be made to unwind slowly and evenly.

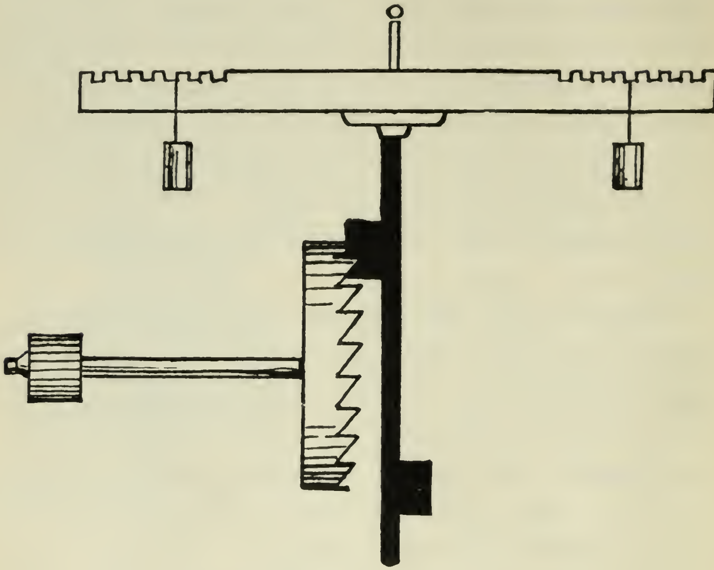
A Few Words About Rabbits

To understand how the regulators in the earliest clocks work you must recall trips along the Neva in a little steamboat. (American boys and girls will recall other boat trips on other rivers. But this book was first written for the school children of Leningrad.) When you went out on the landing pier, if you remember, you had to pass through a turnstile —an arrangement which prevented the passengers from all crowding on to the landing together and forced them to go one by one. Such turnstiles are often placed at the entrances to public gardens, too, to make it easier to catch the rabbits who try to steal into the garden—not four-legged but two-legged rabbits.

When you pass through the turnstile you push it forward. It turns round and blocks the way for the person behind you. Imagine now that the weights, when they are released, have not only to turn a windlass but also a little cog wheel connected with it. This is not a difficult thing to do and we shall see in a moment how it is done.

We must somehow hold back, slow down, the revolutions of this wheel. To do this we shall have to hold back the teeth of the little wheel, just as the turnstile holds back the people passing through it.

The picture shows this little wheel. The turnstile, or regulator, is the axle with two projecting flanges. In the picture the upper flange is caught between two of the upper teeth of the cog wheel. The tooth which the flange hinders from advancing pushes it forward and this causes the axis to make a half revolution and then the lower flange catches between



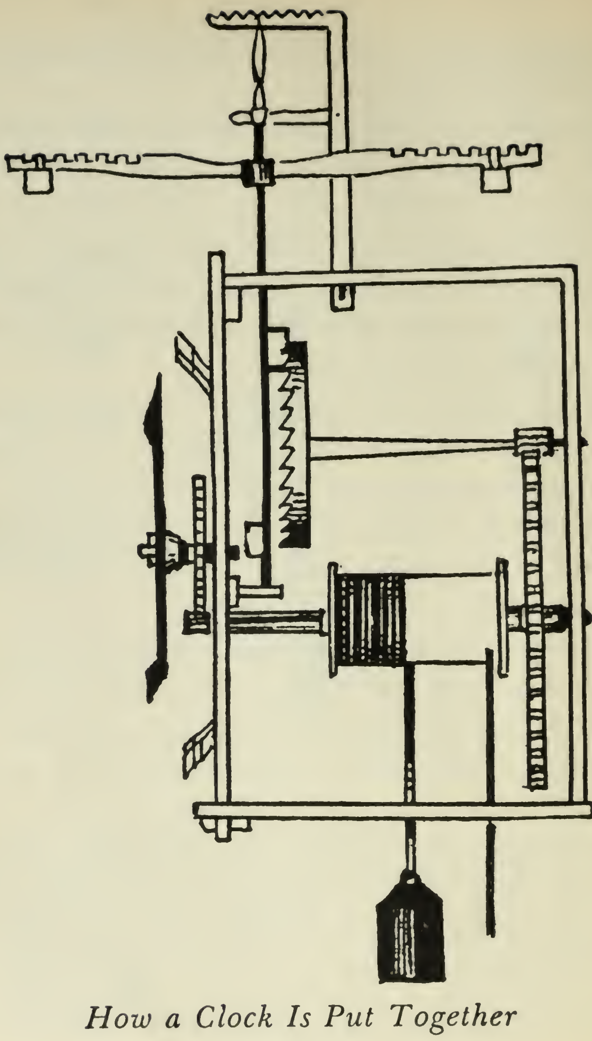
The Turnstile in a Clock

two lower teeth—and so it goes on. But to prevent the cog wheel from turning the turnstile too easily a bar with two little weights on it is placed across the upper end of the axle. Without this regulator the weight would fall rapidly down. But when we force it to turn this weighted bar we have given it such hard work to do that it goes slowly and regularly—by little jerks.

You can see in the picture how a clock is put together. You can, of course, see which is the weight, which is the windlass, the cog wheel with its turnstile. (The cog wheel is called the escape wheel and the turnstile is called the balance.) At the left the hands are pictured. You have a side view of the dial so the figures are not represented.

The windlass, as it turns, sets the whole mechanism in motion—hands and regulator. To transmit the movement there are two sets of cog wheels. The one at the left, pinion and cog wheel, transmits this motion to the hands. The other set, at the right, turns the axle of the starting wheel.

The first clocks were very simple and crude compared with ours and showed the time very inaccurately. In the first place they had only one hand, an hour hand. They had to be wound several times a day. That's why Henry de Viek had to live in the tower with his clock. It was very capricious and had to be carefully tended. The figures on the dial plates of these early clocks were from one to twenty-four, not like ours from one to twelve. They struck one o'clock after sunset and twenty-four at sunset of the



How a Clock Is Put Together

following day. In olden times it was customary to reckon the day as from sunset to sunset and not, as we do, from midnight of one day to midnight of the next.

Later, changes were made in the dial. The figures one to twelve were written twice, once for night and once for day-time. But they soon began to reckon the time as we do to-day.

It is interesting to note that we are now beginning again to reckon the hours from naught to twenty-four. In the armies of some nations and on many railroads this has been the practice for a long time. Though most of us still prefer to say half-past twelve at night instead of twelve-thirty, or eleven o'clock in the evening instead of twenty-three o'clock.

Big Tom's Joke

The clock which hangs in my room is not averse to having a bit of fun now and then. To-day, for instance, it struck fourteen instead of twelve at noon time. If this happens even with our cleverly made clocks what could be expected of those which our grandfathers had?

Big Tom of Westminster played a trick like this one day, apparently forgetting for once that he was not Little Tom. And it happened that this joke saved a man's life. This is the way they tell the story: There was once a guard whose duty it was to stand in front of the king's palace in London. One evening as he was leaning on his musket, thinking how cold and foggy the night was and how long it would be before he was relieved by the next watch, he suddenly heard muffled voices near by. He lifted up his head and began to listen, peering out into the darkness. They didn't light the streets at night in those days and it was hard to distinguish anything in the dark. The guard made a few steps along the palace, but the noise was not repeated. Just at this moment the clock on Westminster tower struck the hour.

Now Big Tom was a good friend of our musketeer. The strokes of the bell made the time, which dragged along so slowly, seem shorter. The guard began to count the strokes, keeping time with the butt of his gun on the ground. At the twelfth stroke he added one more, making thirteen in all.

Next day the guard was arrested. It seems that at midnight of the previous night a valuable necklace had been stolen from one of the queen's private rooms. They accused our friend of having been asleep at his post so that he failed to hear the thieves when they went from the street into the palace.

It would have gone hard with the poor man if he had not been able to prove that he was not asleep at midnight. But fortunately he remembered in time the thirteen strokes of Big Tom and told about it to prove that he had not been asleep. They sent for the man who lived in the tower and looked after the clock and sure enough he confirmed the story that the guard had told, and said that the clock had struck thirteen times instead of twelve. There was nothing to be said against such a witness, so

Big Tom and the Musketeer

they let the musketeer go. Big Tom saved his friend's life.

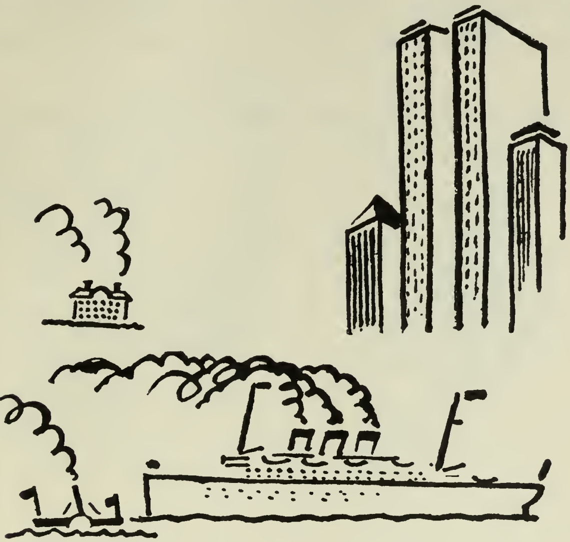
Nuremberg Eggs and What Was Hatched from Them

Have you ever noticed how things grow? Two hundred years ago a three story house was a rarity, and now they build houses of one hundred stories and more in America. The first little steamboat was a dwarf compared with the ocean giants of to-day. You could find thousands of such examples of how things grow.

With clocks the case is just the opposite. The first mechanical clocks were huge tower clocks whose weights weighed several hundred pounds. Many years passed before clocks shrank to the size of our wall clocks, table clocks, and watches.

Big Tom was two hundred years old when, at the command of Louis XI, King of France, the first portable clock was made. It wasn't so very small and certainly it could not be carried about in a pocket. When the king made a journey the box in which this clock was carried was loaded onto the back of a pack horse. There was a special groom whose duty was to look after both the horse and the clock. One wonders if he sometimes confused his two duties and gave oats to the clock or tried to wind up the horse.

It was about the year 1500 when the pocket watch



at last made its appearance. Its inventor was a clock maker of the German town of Nuremberg, Peter Henlein. They say that when he was still but a little boy he astonished every one by his cleverness. And indeed the problem which he had to solve was one for a very clever man.

The very greatest difficulty was what to use for a motor in place of weights. Peter Henlein thought up using a spring. Now the chief characteristic of a spring is its stubbornness. No matter how you wind it up it always tries to unwind itself. And it was just this quality, often a very unpleasant one in people, which Peter Henlein decided to make use of.

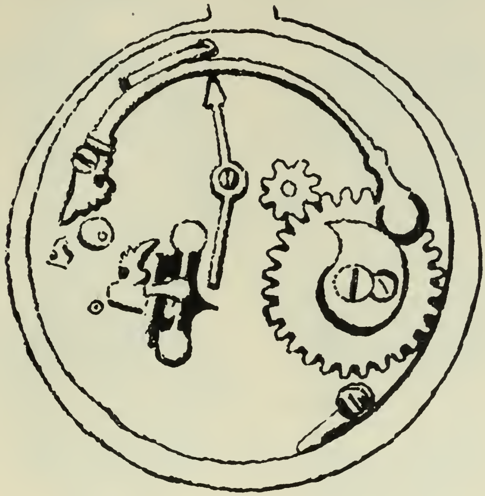
Inside the works of a pocket watch there is concealed a little flat box made of brass. This "drum"

is the little house in which is kept the engine which makes the watch go, the spring. One end of this spring, the inside end, is immovable. It is fastened to an axle on which the drum rests. The other end, the outer end, is attached to the wall of the drum.

When we wind up the watch we turn this drum round and at the same time wind up the spring and make the outer end describe circles. But as soon as we leave the spring to itself it begins to unwind, the outer end returns to its former position and the drum makes just as many revolutions backwards as it had previously made forwards.

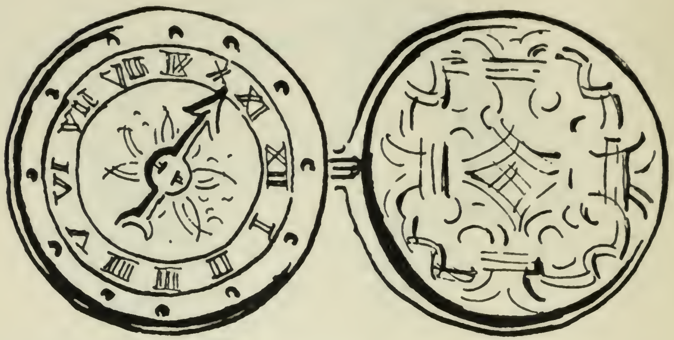
That's the whole trick.

A number of cog wheels transmit the revolutions of the drum to the hands, just as in the clock with weights. To slow up the unwinding of the spring Peter Henlein made use of the same kind of balance as that used in the big clocks.



An Iron Watch Made by Peter Henlein

The picture shows an iron watch made, apparently, by Peter Henlein himself. The back case of the watch is removed so that you can see the mechanism. At the right is a large cog wheel which rests on the same axis as the drum. The drum is under this cog wheel. This large cog wheel is used to wind up the watch. The key fits into the rectangular axis of the little wheel and turns it. The little wheel then turns the big wheel and the drum. Other wheels, which transmit the motion to the hands, are concealed under the plate which covers the inner part of the works. At the left is a little balance with two



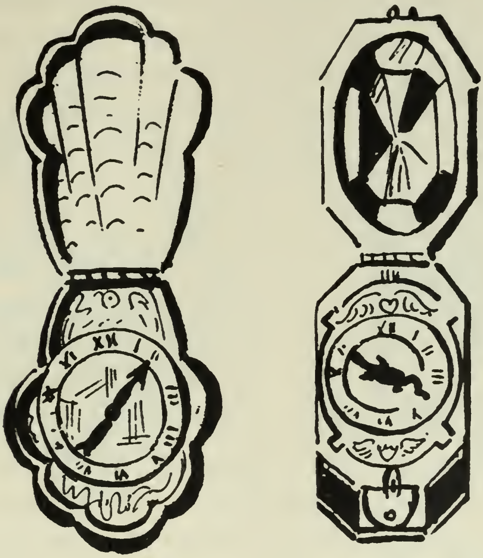
Watch with Knobs

little weights, like the bar with weights which we saw in the big clocks.

This watch has only one hand, and has no crystal. Above each figure is a little boss or knob so that you could tell the time in the dark by feeling.

The little knobs had another purpose too. In the old days it was considered very impolite for a guest to look at his watch. If you looked at your watch your host might think that he was boring you. So when a guest wanted to leave, he cautiously put his hand into the pocket of his waistcoat and felt for the hand and the little knob near it.

Nowadays it is just the opposite—guests may look



Nuremberg Eggs

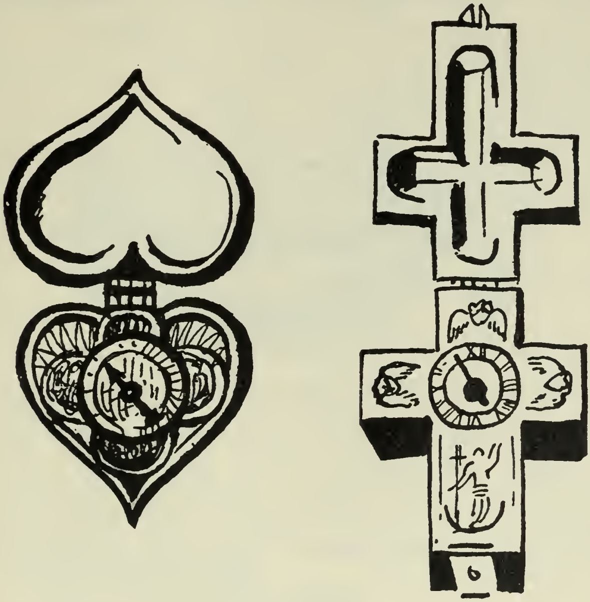
at their watches as often as they please, but the host must wait resignedly until his guests leave, not daring to take his watch out of his pocket.

The first pocket watches were called "Nuremberg eggs." Many of them were really made in the shape of an egg. But very soon they began to make watches of all kinds of shapes. There were stars and butterflies and books and hearts and lilies and acorns and crosses and skulls—anything and everything you like. These watches were often decorated with miniatures, inlaid with enamel, and set with precious stones. It seemed a pity to hide such beautiful little objects in the pocket so people began to wear them hung round their necks or pinned on their breasts. Some

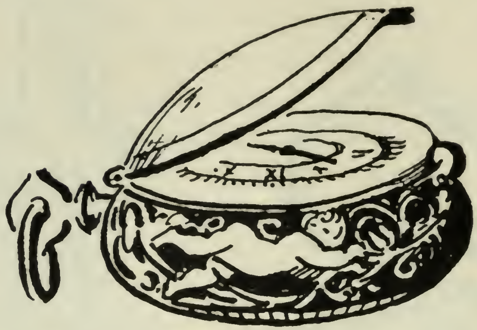
dandies wore two watches, a gold one and a silver one, to show how rich they were. It wasn't considered the thing to carry your watch hidden in your pocket.

Watchmakers now became so expert that they made tiny little watches that could be worn as an earring or set in a ring in place of a precious stone. The Danish queen who married the English King James I, had a ring with a tiny watch set in it. This little watch struck the hours too, but not with a bell. There was a tiny little hammer which with light touch pounded out the hours on the finger of the wearer.

It is amazing what wonderful things hatched out of those Nuremberg eggs! What skill a man had to have to make such a ring! And in those times all work had to be done by hand too. Nowadays, when watches are manufactured by machinery, the watch



makers only have to assemble the different parts which are all cut out by machinery. They have every possible kind of lathe and machine for cutting out the teeth, etc. It's no wonder that watches are cheaper now and that nearly every one can have one. In the times of which we are speaking it was still no easy job to make a watch and not so very good a one at that. And they were extremely expensive. It was no wonder that kings were in the habit of presenting their courtiers with watches

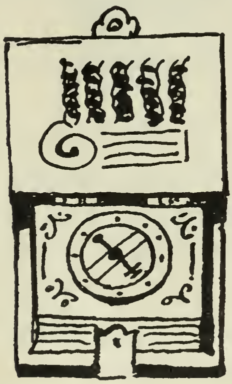


when they wanted to reward them. In the time of the French Revolution many doctors and apothecaries who had formerly been the servitors of the court tried in every way to get rid of such royal gifts for which they might have to pay with their heads.

The Duke and the Pickpocket

Once upon a time at a reception of the Duke d'Orleans an amusing incident occurred. The duke had a very fine watch which had cost a great deal of money. The reception was about over when the duke noticed that his watch was missing. One of his adjutants, hearing of the loss, exclaimed:

"My lord, we must lock the doors and search every one. Some one has stolen your highness' watch!"

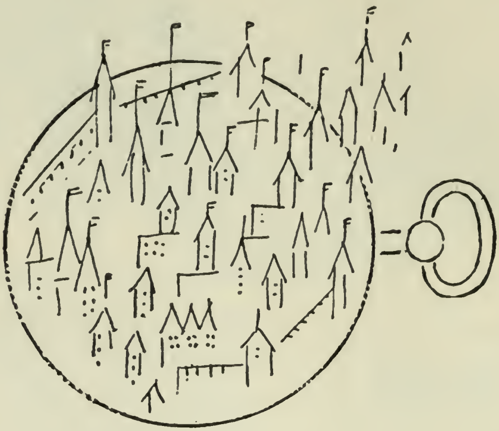


But the duke, who thought himself a very cunning fellow, said:

"No, we don't need to make a search. The watch strikes. It will give away the thief in less than half an hour."

However, the watch wasn't found. Apparently the thief was smarter than the duke and stopped the watch in time.

Watches which struck the hours weren't always convenient. They struck every half hour and were a great interruption to conversation, so they say. Perhaps that's the reason they went out of use. Later some English watchmakers succeeded in making some watches that struck only when the stem was



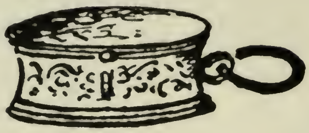
pressed. I once saw a watch of this kind, with a "repeater." When you pressed down on the stem it gave out an unusual, musical sound. Little hammers beat out first the hour, then the quarter, and finally the minutes. One felt, involuntarily, that this sweet, plaintive sound came from some other world; that it was the faint tinkle of the bells in some fairy city, from which you were separated only by the gold case of the watch.

King Charles II sent one of the lately invented "repeating" watches as a present to Louis XIV of France. So as to make it impossible to discover the inventor's secret, the English watchmaker put a lock on the case that could not be opened in France. It was absolutely impossible to open the case and look

at the works. No matter how hard the king's watchmaker, Martini, worked at it, he couldn't possibly get it open. Upon his advice they sent to the Carmelite monastery for the ninety-year-old watchmaker, Jean Truchet, who was ending his days there.

They gave this old man the job of opening the watch, but didn't tell him whose watch it was. Truchet opened the case with very little trouble and discovered the secret of the English craftsman.

How surprised he was when they informed him that he had been given a pension of six hundred livres a year for his work.



Jacquemar and His Wife

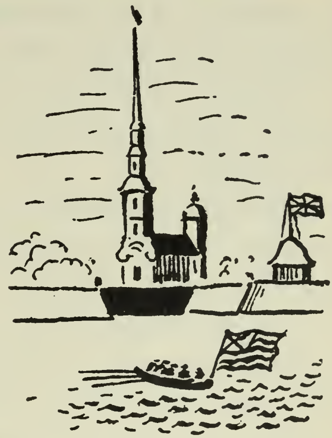
If you ever happen to spend any time in the French city of Dijon they will surely show you Jacquemar and his wife. Jacquemar is a middle-aged man, broad-shouldered and thickset, with a pipe between his teeth. His wife is just like the other peasant women who come into Dijon from the surrounding country on market days. Yet Jacquemar is famous throughout the whole world. There is a poem composed in his honor called "The Marriage of Jacquemar." The citizens of Dijon always look at this pair very respectfully—that is, they look up to them. It is the only way they can look at them, for the Jacquemars never come down from the high clock tower in which they live. They were put up there to strike the hours on a big hollow bell with the hammers they hold in their hands.

Jacquemars

The Jacquemars were put up there long, long ago, at about the same time that the clock of Henry de Viek was built. They say that these bronze figures are called Jacquemar from the name of the man who made them and the clock. They strike the hours and afterwards a small youngster comes out to strike the quarters.

Years went by, and centuries. Here and there, in large and small towns, appeared clocks with sets of bells, or chimes. The construction of some of them is much like that of a music box. The clock's mechanism lifts up the hammers, like keys on a piano, then releases them and the little hammer falls on a bell and makes it ring.

There were chimes of another sort too, with keys. These were played on just as we play on a piano. The bells were so arranged that the first one would give the sound of *do,* the second *re,* the third *mi,* etc., so that it was possible to play all kinds of tunes on them. There were chimes with thirty and even forty bells. At one time these chimes were very popular, especially in Holland. It was probably there that Peter the Great got his passion for chimes. Chimes, imported from abroad at great expense, were placed in many of the churches of St. Petersburg. As no one in Russia knew how to play them they had to import artists from abroad to perform on these chimes. The Russians called them "Chime-playing musicians." An entry has come down from those times in which we read that: "On April 23, 1724, an agreement was made with the foreign born chime-playing musician, Johannes Christos Furster, that he was to take service with his Imperial Highness for three years in the fortress of St. Petersburg, to play the chimes on the spire of Peter and Paul."



These chimes now play the "International" for Soviet citizens.

Peter the Great had some other famous chimes made of glass bells which were set in motion by water, like a water clock. In the year 1725 there was a big illumination in Peterhof. One of the persons present at that festival tells how every one was amazed by these water chimes, or, as they said in those days, "the little bells that go by water."

Two Boys

You remember that we said in the beginning of this book that you could measure time in thousands of ways: by the number of pages you have read, by the amount of oil consumed in a lamp, etc. I was talking not long ago with a boy and he said:

"Couldn't you measure time by beating on the ground with the toe of your boot and keeping count of the beats?"

Before I could answer, my young friend saw himself that this plan wouldn't work. You see, there wouldn't always be just the same length of time between the beats—not to mention how exhausting this work would be, to keep on striking the ground with your foot for an indefinite period. You can measure time only by means of something that always lasts just the same length of time. You can see that no one would use a measure that was sometimes longer and sometimes shorter.

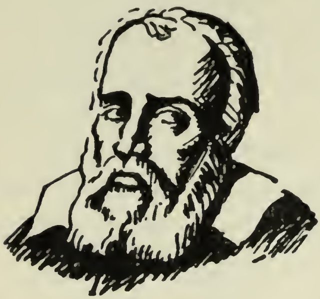
Long, long ago people began to ponder about the question: What always lasts exactly the same length of time? One said: From the time the sun rises one day until it rises the next is always just the same length of time—a day. This was correct. So they began to build clocks in which the sun itself showed the time. But these clocks were very inconvenient in many ways. You have seen why.

Others solved the problem in another way. Water, they said, always flows out of a given vessel in the same length of time. And this is true. But you must always have just the same amount of water, the opening must never become clogged with dirt, and many other things must be taken into account in order that a water clock shall work right. Furthermore, the best water clocks, those invented by Ktesibius, showed only the hours. Minutes were not even taken into consideration. And these clocks were very easily damaged, too. Just let a little tube get clogged and presto! the whole thing stopped.

Clocks with weights were simple and more reliable. But here, too, you couldn't be certain that the weight would come down evenly. No wonder that clocks were wrong much oftener than they are now. They had to be made very carefully and checked by the sun to keep them running even passably well.

All these clocks, of course, did measure time incomparably better than the boot which the boy suggested—but still they were far from accurate.

About two hundred fifty years ago there was another boy who was looking for something that always lasts exactly the same length of time. His name was Galileo Galilei. He afterwards became a famous scholar and came very near being burned at the stake because the earth revolves on its axis. To be sure, he couldn't change the arrangement of the solar system and make the sun revolve round the earth. But he had the courage to affirm, in those dark days of ignorance, what every first grade school child knows to-day. And for this they almost burned him at the stake in the presence of his fellow citizens, "without the shedding of a drop of blood," as they used to say.



Galileo

They tell the story about Galileo that while he was still only a boy he happened one day to be in church while mass was being celebrated. His attention was wholly centred on a big lamp which hung not far from him by a long chain attached to the cupola. Some one had struck this lamp with his head or shoulders and it was slowly swinging back and forth.

It seemed to Galileo that all the oscillations lasted exactly the same length of time. Gradually they grew shorter and shorter, until the lamp was at last perfectly still—but for a long time the oscillations were uniform.

Afterwards Galileo tested out his observations. He noticed that all pendulums, that is, weights suspended by cords, make their oscillations in the same length of time, if the cords by which they are suspended are of the same length. The shorter the cord the shorter the duration of the oscillation.

You can make a number of pendulums of different lengths and hang them on the head of your bed. If you set them in motion you will notice that the short pendulums swing back and forth more frequently than the longer ones and that those of the same length swing identically. You can make a pendulum of such a length that each of its oscillations to the right and the left will last exactly a second. For this the cord should be exactly a meter long.

When Galileo had made all these observations he realized that he had at last discovered the answer to the old riddle—he had found something that always lasts exactly the same length of time. He began to think about how to use the pendulum in clocks. How to make it so that the pendulum would regulate the pace of the clock. But he didn't succeed in making such a clock. This was accomplished by another famous scholar, Christian Hugens.

What the Pendulum Said

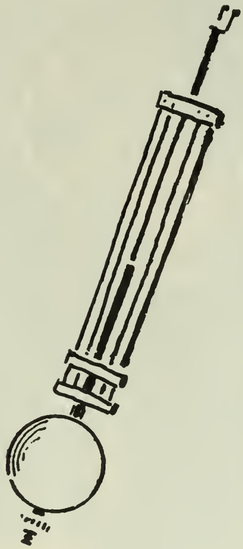
I remember that in my early childhood before I knew what clocks were for, the pendulum of our big clock seemed to me something like a stern person who never stopped repeating some admonition, as:

You mustn't, mustn't
Suck your thumb!

Later, when I had mastered the difficult science of knowing by the position of the hands what time of day it was, I could not get entirely rid of a certain feeling of fear which the clock roused in me. The complicated life of the many wheels seemed to me a secret which I could never understand.

But the construction of a clock is, after all, not so very complicated. On the next page there is a drawing of a wall clock with a pendulum. You will not have any difficulty in finding the weight here, and the drum round which the rope is wound. The cog wheel turns round with the drum. This first wheel turns a little pinion and with it the clock wheel which is attached to the same axis. This wheel is called the clock wheel because the hands of the clock are fastened to it.

The clock wheel turns another pinion and with it the escape wheel. The whole thing is constructed



A Pendulum

just as clocks were before the time of Galileo and Hugens. The difference is that here there are no windlass and balance. Their places are taken by another arrangement which holds back the escape wheel and doesn't let the weight go down too fast. Above the escape wheel there is a curved plate that

The Works of a Pendulum Clock

looks like an anchor. And it *is* called an anchor. This anchor moves all the time with the pendulum which hangs behind the works.

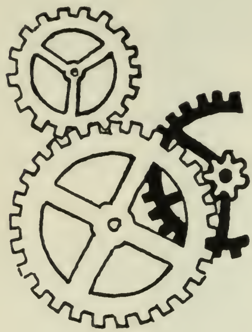
Suppose that the left hook of the anchor is caught between the teeth of the escape wheel. The wheel stops for a moment. But the weight immediately does its work and forces the wheel to push out the hook that is holding it back. This push makes the hook lift up and lets one tooth of the wheel go by. But the push makes the pendulum oscillate to the left, and the right hook of the anchor comes down and again stops the escape wheel.

This goes on and on. The pendulum oscillates from right to left, not allowing the wheel to move forward more than one tooth at each oscillation. Now we know that every oscillation of the pendulum is identical. So it is clear that the pendulum makes the whole mechanism work evenly, correctly, and with it the clock hands will advance by little steps of just the right length and all of the same length.

On our clocks nowadays we have also minute and second hands. More little cog wheels had to be added to take care of them. But this is a detail which it is not necessary to dwell on.

You may ask: The pendulum swings back and forth at a fairly rapid rate. That means that the escape wheel must move rapidly. Why, then, does the clock wheel, which is connected with it, go so slowly that it takes it twelve hours to make one revolution?

The answer is that the wheel and the pinions are so arranged that each one revolves at exactly the required speed. Suppose that a certain pinion has six teeth and the cog in which it meshes has seventy-two teeth. While the wheel is making one revolution the pinion will make as many revolutions as six goes into seventy-two. That is, the pinion will revolve twelve times as fast as the wheel. All we have to do, then, is to work out the required number of teeth for the various wheels and pinions.



So that the clock wheel will not have to have too many teeth, an extra set of cogs (cog wheel and pinion) is placed between it and the escape wheel. You can, for example, arrange it so that the clock wheel will go twelve times as slowly as the extra pair and make them go sixty times as slowly as the escape wheel. Then everything will be fine. The clock wheel will not have to be too large and its speed will be just what is required.

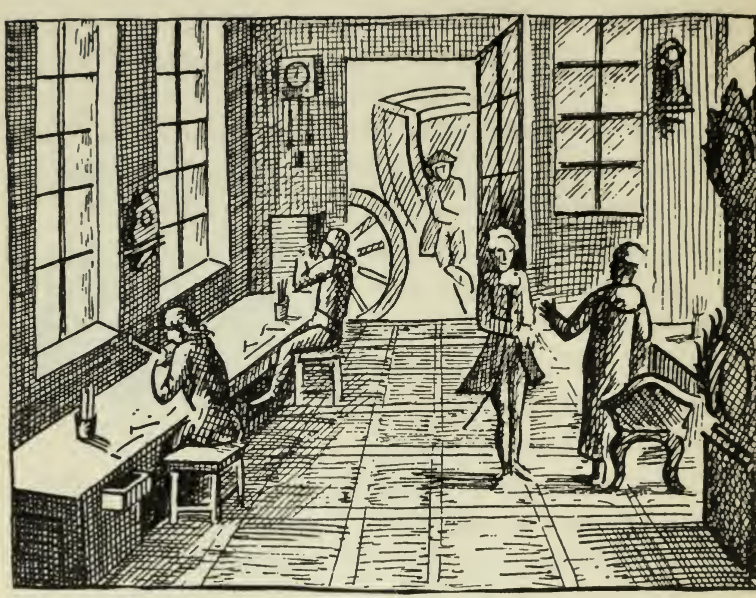
Engineers of Former Centuries

After the invention of the pendulum the clock became at last an accurate instrument. Improvements are always being made and will continue to be made in its construction and clocks and watches will grow cheaper and more accessible.

That is always the case.

When radio was first invented only a few people knew about it, and they only by hearsay. But the more scientists and amateur experimenters worked at improving radio apparatus the better and more accessible it became. And now no one is surprised to see whole forests of antennæ rising above houses anywhere in the country.

It is true that things did not move quite so fast in the case of the clock as with radio. Two hundred years after Henry de Viek constructed his clock it was still easier to find water or sand clocks than mechanical ones. The guild of Paris clock-makers, which had just come into existence, consisted at that time of only seven men. Two hundred years later,



An Eighteenth Century Watchmaker's Shop

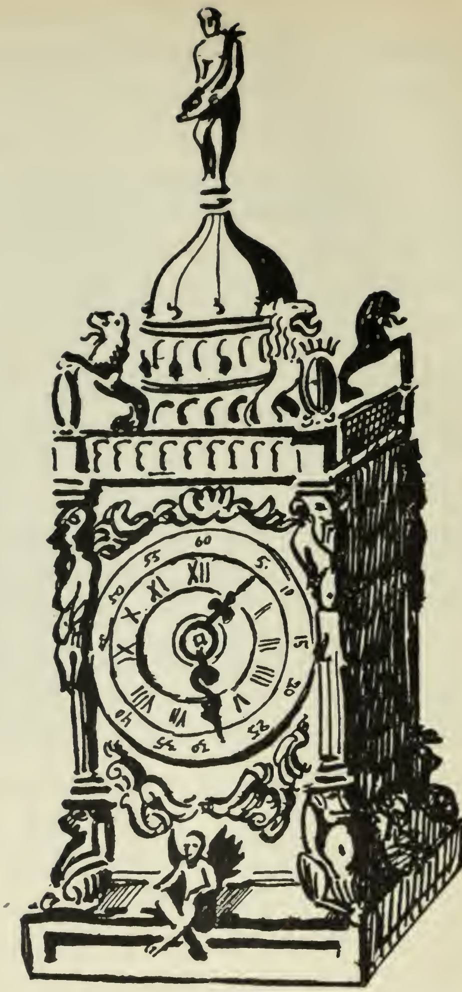
it had one hundred and eighty members and even cab drivers were beginning to own clocks.

If we could go back to the eighteenth century and take a peep into a clock-maker's shop we should see a big room with long tables along the walls. At these tables there would be several men working, dressed in smocks. These are the journeymen clock makers. Seated on leather-covered stools, worn by long usage, they are engaged in their painstaking work. On the tables are a lot of little files and hammers of every imaginable kind, but not one machine, not one lathe, will you find in the whole establishment. Everything is done by hand. And how skillfully it was done!

See that watch, for instance, which represents a building with a light dome, supported at the four corners by bearded giants. The little walls are ornamented with delicate, embossed designs. Many little figures representing lions, griffins, and other fantastic animals are carved round the dome and on the pediment.

But where is the owner of the shop? There he is, standing talking with a court dandy who has come to buy a watch. The old master watchmaker, in long caftan and peaked cap, is trying to explain to his distinguished customer that he cannot let the watch go on credit. You see, his highness already owes him some five hundred pounds.

Through the open door you can see the carriage of his highness—a clumsy coach with huge wheels and ornate windows with curved glass panes.



A Music Clock

It looks, though, as if the old man is going to give in. It is a bit dangerous to quarrel with such distinguished personages. If you're not careful it may land you in the Bastille.

To be a good watchmaker one had to be a good mechanic. There were no technical schools in those days. Knowledge was handed down from father to son, from master to journeyman. It is not to be wondered at that most of the talented inventors of former times were watchmakers. The inventor of the spinning machine, Arkwright, was a watchmaker. They called him the "Nottingham watchmaker." Hargreaves, who made the "Jenny," a machine for spinning fine threads, was a watchmaker. And the inventor of the steamboat, Fulton, was also a master of the craft of watchmaking.

R. FULTON

Those engineers didn't study in technological institutions, but in the watchmaker's shop, sitting on little leather-covered stools. And all the machines which they invented are still in use, in changed and improved forms, of course.

But that's not all. The hands of these watchmakers, those very hands which were in the habit of dealing with such minute things, did a very great work.

After the appearance of spinning machines, weaving machines, steam engines and other machines, hand work gave way to machine work. Stone factories and mills sprang up on every hand. Peasants left the country and went to the cities to look for jobs. Everything in the world changed. The eighteenth century isn't so very far away from us, yet in those one hundred or one hundred and fifty years a greater change has taken place than in the preceding one thousand years. And all this was brought about by the mechanic-inventors of machines, among whom watchmakers are by no means at the bottom of the list.

Mechanical Men

There are many wonderful stories told about artificial, mechanical men, who obediently perform every service. All you have to do is to press the right button. There is, for instance, the tale of an inventor of such manikins who hadn't a single live servant in his house. Everything was done by manikins who were noiseless, accurate, and prompt. As he thought that manikins had no use for heads this inventor made all his headless.

But it is not at all necessary to make machines in the form of human beings. If you were in a textile factory you would see machines that do the work faster and better than a thousand spinners. How silly it would be to make a thousand artificial women with spindles in their hands instead of one big machine!

Arkwright, Hargreaves, and the other inventors of the first machines understood this very well. But there were some watchmakers who loved to make these mechanical men. And some of them did surely succeed in constructing manikins which were very marvelous, although quite useless, toys.

In the "Saint Petersburg Gazette," No. 59, 1779, there is the following advertisement:

"By permission of the Chief of Police there will be exhibited in this city, near the Kazan Cathedral, a mechanical musical machine such as has never before been seen here. It consists of a fashionably dressed lady who sits on a stool and plays on a clavecin which is placed in front of her. She plays ten popular compositions, that is, three minuets, four arias, two polonaises, and one march. She renders the most difficult passages at an incredible tempo. At the beginning of every piece she bows politely to the audience. People who are proficient in mechanics, or interested in the arts in general, will be delighted by the free movements of her hands, the natural expression in her eyes, and the graceful, easy movements of her head. No spectator can fail to

be thrilled. This mechanism is exhibited daily from nine in the morning to ten in the evening. Ordinary persons are charged fifty kopeks for admission. Persons of distinction will pay whatever they see fit."

And there were even more wonderful mechanical men. A Frenchman made a flute player who played twelve different selections on his flute. His fingers moved so rapidly that it seemed as if the hands must be living.

The most famous of all the makers of these mechanical men were the Swiss mechanic, Droz, and his son. One of the toys they concocted represented a child who is sitting on a stool before a small table, writing. From time to time he dips his pen into the ink, takes it out and wipes off the superfluous ink. In a beautiful handwriting he writes out whole sentences, puts in the proper letters, spaces the words, and on finishing one line goes back and begins the next in the proper place. Every once in a while he glances into a book lying on the table from which he is copying out his lesson.

Another toy represented a dog holding a basket of apples. If you took an apple from the basket the dog began to bark so naturally that if there were any real dogs in the neighbourhood they would begin to bark in reply.

Among other things the Drozes also made a mechanical woman musical performer, who played on the clavecin. Perhaps this was the "musical machine" which was exhibited at Petersburg.

But the most remarkable creation of the Drozes was a marionette theatre which gave a whole little play. The scene represented an Alpine meadow, surrounded by high mountains. A drove of sheep, tended by their shepherd, were grazing in the meadow. At the foot of the mountain was a peasant's cottage and on the opposite side of the valley stood a mill on the banks of a little stream.

The action is begun by the peasant's riding out of his court-yard gate on a little donkey. He is going to the mill. When he rides along near the sheep the dog begins to bark and the shepherd comes out of a little cave near by to see what is the matter. Before he goes back into his grotto he takes out a pipe and plays a lovely little melody on it, which is echoed back from the mountains.

Meantime the peasant crosses the little bridge over the brook and rides into the mill yard. He comes back on foot, leading the donkey, who is loaded with two bags of flour. He returns to his cottage, the shepherd goes back into his grotto, and the scene is again just as it was before the performance began.

I mustn't forget to add that there was a sky over this little valley across which the sun climbed. When the clock hands pointed to twelve o'clock the sun had reached the highest point of its journey and began to descend.

We have had some very clever makers of mechanical toys, in Russia, too. In the Leningrad museum which shows the history of serfdom, there is a droshky with a music box and a device for measuring the distance traversed. When you travelled in this droshky the music box entertained you with songs and marches and the meter counted out the versts, sagens, and arsines. On the back of the music box there is carved a portrait of a man with a big beard, dressed in a peasant's caftan. Under the portrait is this inscription:

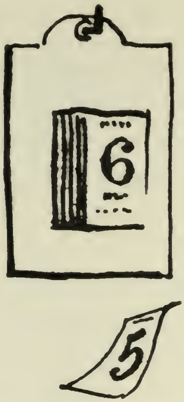
"The maker of this droshky was Egor Gregoriev Zhelinski, an inhabitant of Nizhni Tagil factory. He made it because he was interested in study and in curious learning. It was begun in 1785 and finished in 1801."

It is appalling to think of a man's spending twenty-six years of his life in making a toy—amusing, but absolutely useless. But this was in the days of serfdom when no account was taken of human labour.

Another self-taught Russian, Kulibin, made a clock of the size of an egg, which struck the hours, half hours, and quarter hours. Every hour a door in the centre of the egg opened. Inside the egg were a number of little figures. They played on chimes and the door closed again.

Kulibin also invented a "self-propelling" boat.

It is interesting to note, too, that one of the Drozes made a very curious steam engine with a wooden boiler. This was a strange time, when, besides making "self-propelling boats" and steam engines, engineers spent their time inventing mechanical dogs and shepherds; when, in the words of Pushkin, "drawing rooms were full of all kinds of ladies' toys, invented toward the end of the eighteenth century at the same time as Montgolfier's balloon." [1]



The Wonders of Strassburg Cathedral

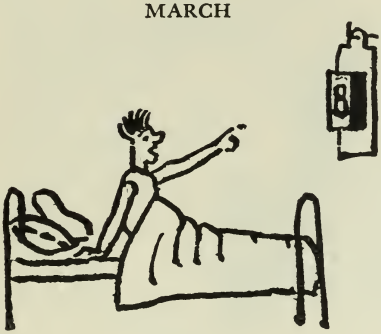
We make use of mechanical means for reckoning hours, but we still keep track of the days almost as simply as Robinson Crusoe, who made a notch on his stick every day. Why is it that we don't make mechanical calendars too? Imagine a calendar that would have to be wound up, say, once a year, or, better still, every ten years. Every night, at exactly twelve o'clock a leaf would loosen itself and fall whirling to the floor, like a leaf from a tree.

Such a calendar would be a boon to scatter-

[1] The first balloon was made by the Montgolfier brothers.

brained people who sometimes tear two leaves off the calendar at once, instead of one, or forget to tear off any leaves at all for a month or more. And what mishaps this can cause! On Thursday this scatter-brained fellow forgets to go to his meeting because his calendar says in black on white

TUESDAY
8
MARCH



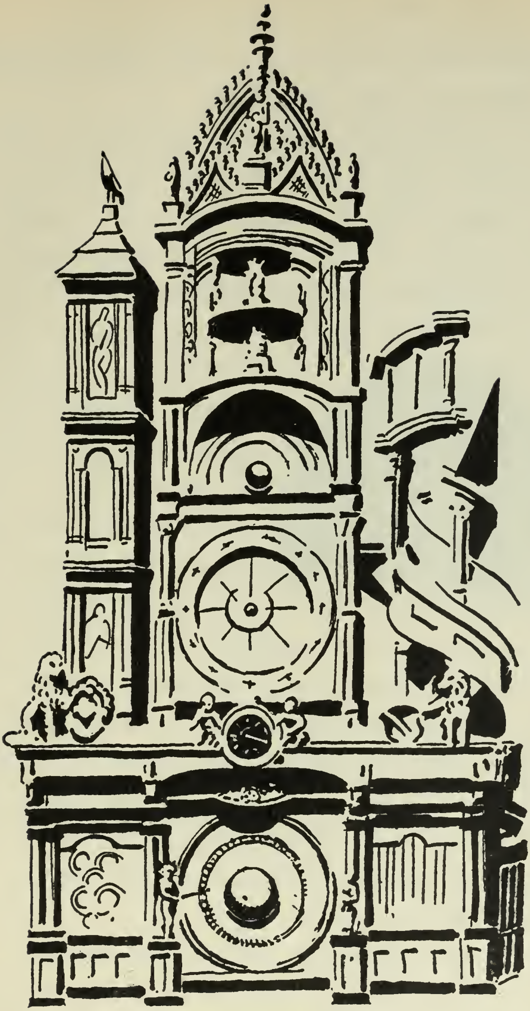
And on his day off he goes to work because his treacherous calendar has not yet parted with yesterday.

In the days when it was the style to invent all kinds of mechanical novelties there were some mechanical calendars. The most famous of these is still to be seen in the city of Strassburg. There is, in this city, an old cathedral. The building of this cathedral went on for several centuries, and still it was never really finished. Of the two towers which, according to the architect's plans, were to rise above the broad heavy building, only one lifts up its sharp pointed spire to the sky.

Inside the cathedral, under a high stained-glass window, there is a miniature copy of the large cathedral, with the same sharp pointed tower. This is the famous clock of Strassburg Cathedral.

On the tower there are three dials. The lower one is a calendar: a huge, revolving circle, divided into three hundred and sixty-five parts—the days of the year. At one side are the figures of Apollo, the god of the sun, and Diana, goddess of the moon. An arrow in Apollo's hand points to the day.

Every year, on the 31st of December at twelve o'clock at night, all the days of the week take new positions. Such holidays as Easter, which are on different dates every year, arrange themselves in their



Schwilgué's Clock

necessary order. If the year is a leap year an extra day, February 29th, is added.

This wonderful mechanical calendar is the work of the clock-maker Schwilgué who made the Strassburg clock. The middle dial is a regular clock which tells the hours of the day. But the upper one is a planetarium. If you want to know the position of any planet in the heavens, all you need to do

is to look at this planetarium. Around the circle are arranged the twelve constellations of the Zodiac, as the constellations through which the planets pass are called. Seven hands point to the positions of the seven planets.

Nowadays even more remarkable planetaria are made. The planetaria of our times occupy whole buildings, seating a large number of spectators. Up in the big cupola inside, the stars are shining. The planets travel through the stars. The sun and moon rise and set. In the centre of the planetarium there is a big reflector which lights up the cupola like a screen, and shows up the stars and planets.

There is a planetarium of this kind in Moscow and another in Chicago. They were built not so very long ago. When you sit in them you forget that it isn't really the great open starry sky over your head, but only a metal dome. You forget that the sun is still shining out there in the street, and that it is not night at all, but either a bright sunny day or a cloudy rainy morning.

Tourists who visit Strassburg Cathedral do not find the calendar the most interesting thing to see, nor the planetarium either, but the many little figures which move about and enliven the complicated structure of the clock.

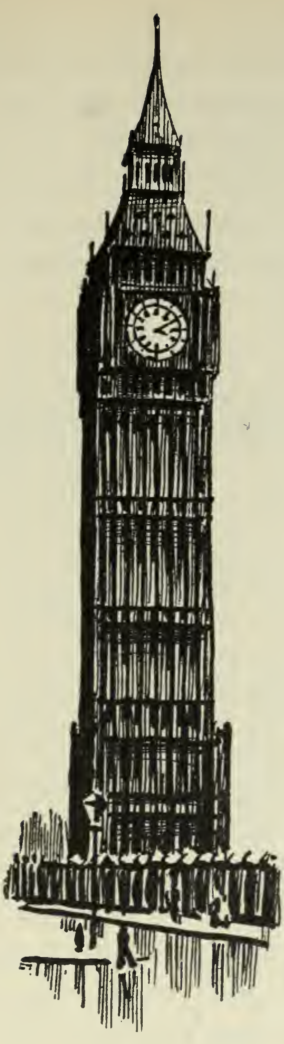
At the upper part of the tower are two little galleries, one above the other. Every quarter of an hour a little human figure runs along the lower gallery. At the first quarter this is a child. Fifteen minutes later a young man takes his place. Fifteen minutes pass and a middle-aged man passes along the gallery. Finally, when the minute hand points to twelve, a tottering old man appears in the gallery. On his shoulders sits Death with his scythe in his hands. So, in the short space of an hour, the spectator sees the whole course of human life pass in review.

Each of these little figures rings out the quarter hour on a set of chimes. At exactly twelve o'clock noon there is a solemn procession of twelve little figures in monkish vestments along the upper gallery. And at this moment there sounds out from the little tower a joyful and far from "solemn" "cock-a-doodle-doo!" This comes from a tiny little figure of a cock who greets the noon hour in his own way.

Big Ben

Big Ben. This is not the name of a negro chieftain nor of a tropical plant. Big Ben is the biggest clock in London, perhaps in the whole world. He lives in Westminster tower, where his grandfather, Big Tom, used to live.

Big Ben has four dials, one for each side of the four-cornered tower. The diameter of each dial is eight metres. If you think this is not so very big just try measuring the length of your room. I'm sure you will find that Big Ben's dial is much bigger.



Big Ben

The minute hand is three and one half metres long. A man compared to this hand would be like an ant compared to a match. Every figure is three-quarters of a metre high. The pendulum weighs more than three grown men, two hundred kilograms. The minute hand moves by jumps of fifteen centimetres each.

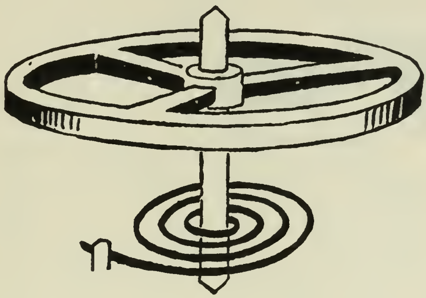
You see what a giant Big Ben is.

Watches Have Pendulums Too

Mechanical men, the Strassburg clock, Big Ben—these are all marvels of clock-making. But the most ordinary little pocket watch is quite a marvel too.

Since the days of Peter Henlein the watch has changed enormously both outside and in. If you remember, in the Nuremberg eggs, the watch was regulated by a balance like that found in these days in clocks with weights. It was Hugens, the man who was the first to use a pendulum in place of the old windlass in wall clocks, who invented a regulator for watches. You haven't forgotten why we have to have a regulator. It must hold back the revolutions of the escape wheel by not allowing the spring to unwind too fast. If the watch is to run correctly these little pauses must be always of exactly the same duration. In wall clocks this is accomplished by the use of the pendulum. All the oscillations of the pendulum are of exactly the same duration and at every oscillation the escape wheel goes one cog ahead.

Now you can't have a pendulum in a watch, because it has to run standing up, lying down, and

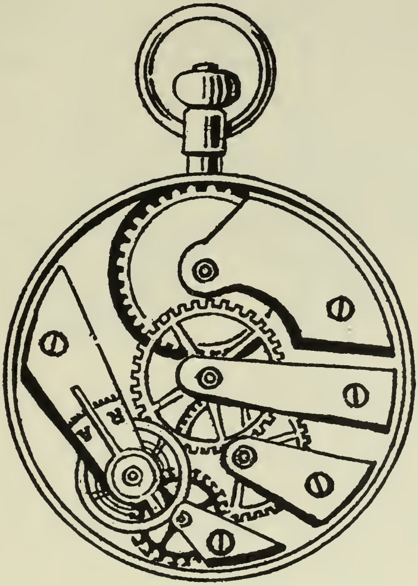


even when it is turning somersaults. But Hugens thought out a pendulum for watches too. This "pendulum" is a flywheel, with one end of a steel spiral spring, the hair spring, attached to its axis. The other end of the hair spring is attached to the immovable plate of the watch.

If you move the flywheel either to the right or to the left, and then release it, it begins to oscillate very much like a pendulum. The reason for this is to be found in that peculiar character of the spring which we have mentioned before, its stubbornness or, in scientific language, its resilience. When we turned the flywheel we wound up the spring. As soon as it was released it began to unwind. If there were no flywheel the spring would unwind instantly, and that would be the end of the matter. But the flywheel acts in the same way as a loaded car—once you start it going it doesn't stop instantly. The heavy

flywheel makes it too hard for the spring to unwind and it goes back in the other direction and winds itself up again. This is repeated over and over. If there were nothing to stop it our balance would keep on going back and forth forever. But the friction of the axle in its axis and the resistance of the air would soon stop the balance if it were not for the mechanism of the watch. The flywheel, like the pendulum of a clock, keeps pushing the balance and makes it oscillate, and this makes the wheel turn at an even pace.

The fact that the pendulum of a clock and the balance wheel of a watch are for the same purpose is not their only point of resemblance. Scientists discovered that the oscillations of a spiral, like those of a pendulum, are always of exactly the same duration; it never happens, for instance, that one oscillation lasts one fifth of a second and another for a longer or a shorter period of time. It was this impor-



The Mechanism of a Watch

tant peculiarity of the spiral which suggested to Hugens that a spiral could be used in a watch in place of a pendulum.

You will probably wonder how the escape wheel makes the balance oscillate, or how the balance holds back the escape wheel. There are two different methods of doing this. In some watches, those of the "anchor" type, it is done by means of an anchor, similar to the one we described in clocks. At every oscillation of the balance wheel the anchor, which is connected with it, holds back the escape wheel, first with one hook, then with the other. And the escape wheel, in turn, pushes the anchor and makes it oscillate, and with it, the balance wheel.

But in many watches the escape wheel is con-

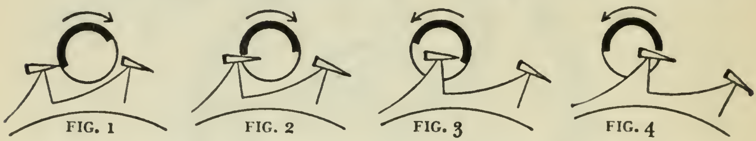
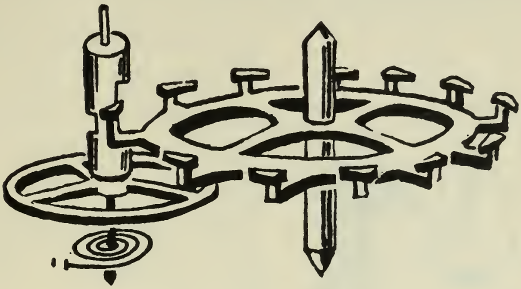


FIG. 1 FIG. 2 FIG. 3 FIG. 4

nected with the balance in another way. The axle of the balance wheel is made in the form of a cylinder with a cutout in one of its sides. This cylinder blocks the way of the escape wheel. Suppose for example that a cog of the escape wheel has just reached the cylinder and collided with its wall (Fig. 1). Halt. Stop. The cog must wait until the hair spring, as it unwinds, brings the cutout round to it and lets it proceed. As the cog goes into the cylinder it presses against the outer edge of the cutout and helps the hair spring turn the cylinder to the right (Fig. 2). But now the cog collides with the inner wall of the cylinder (Fig. 3). Stop again. Again it has to wait until the hair spring going in the opposite direction, turns the cylinder to the left and opens a passage for it. The cog, as it passes out, again presses on the outer edge of the cutout and pushes



the cylinder, helping the hair spring turn it to the left (Fig. 4). And so on until the watch stops.

Watches with this kind of regulator are called cylindrical watches. They are cheaper than the anchor type but not so good. On account of the friction between the cogs and the cylinder these watches gradually wear out, especially if the oil used is of a poor quality.

Prompt Aid When Accidents Happen

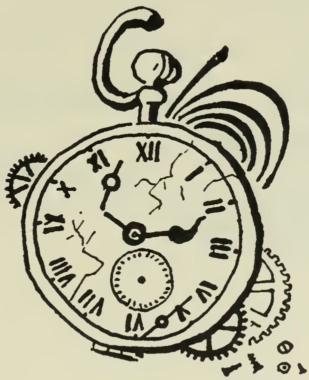
Machines have their illnesses, just like people. The workman who is using a machine has to keep a sharp lookout for its health. He must see that it doesn't get too hot, that the bearings are not burned out by friction. He has to listen for every little squeak or rattle or for any unusual knock or unnecessary noise. In most cases the remedy is very simple—machine oil. Just pour some down among

the labouring parts and everything is fine again. But there are other more serious illnesses, when home remedies do no good. The specialist must be called in, the chief mechanic. The doctor often finds that an operation is indicated and goes to work with his surgical instruments, wrenches, chisels, and hammers.

A watch is a machine. True it's not a very powerful one, only about 1/300,000,000 H.P. But it's a very skittish little machine. The mechanism of a watch is afraid of moisture, dirt, dust, jars. It likes the most expensive oil, that made of bone marrow, or else a specially prepared olive oil.

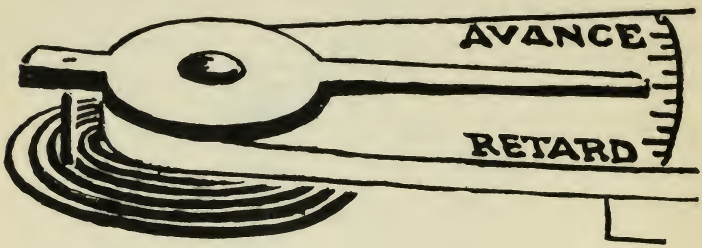
A watch's illnesses may often be cured at home. If your watch stops, first look to see if the minute hand is rubbing against the crystal, or if the hands are caught together. If everything is all right here, open up the case and see if the escape wheel is stopped by a bit of dirt. This can easily be brushed out with a feather.

If the watch loses or gains you must change the position of the regulator, an arrow fastened to one



of the axles of the balance wheel. On one side of this arrow you will find the word "fast" or the letter F, on the other side "slow" or S. On the under side of the short end of this arrow there is a little brad which presses on the hair spring. When we move the arrow from S to F, we change the position of this brad too. The free end of the hair spring, which is not interfered with by anything, thus becomes shorter and therefore more resilient. This makes the balance wheel oscillate more frequently and the watch goes faster.

When we changed the position of the arrow we did not entirely cure the watch's tendency to slow up, however. We only relieved it temporarily. Sooner or later it will begin to slow up again and would finally stop altogether if we did not take it to a



watchmaker to have it cleaned and oiled. The trouble is that the oil used to lubricate the parts deteriorates from contact with the air, becomes acid and grows thick. The spring has to overcome more and more friction all the time, until it is finally unable to do the work required of it and declares a strike.

Sometimes it's even worse than this. The watch stops because a spring is broken. You can tell yourself if this has happened. Try with a sharpened match end to move the centre wheel of the watch, the one nearest the spring, back and forth. If it moves this means that the spring is broken and, willy nilly, you must take it to the watchmaker.

How the watchmaker's workshop reminds one of a hospital ward! One patient is raving and feverishly tears off the hours. Others are hoarse and are exhausting themselves with the effort of coughing and can never be well until the warfare going on in their lungs is ended. Still others are lying in a faint, not making a sound of any kind.

The faint ticking of the little watches, the firm strokes of the big clocks, the rattling and groaning, all mingle in one big noise which makes your head ache if you are not used to it. And in the midst of all this noise and confusion the head physician, the watchmaker, calm and unhurried, goes steadily on with his painstaking work. And the watch, which seems utterly ruined, comes from his experienced hands rejuvenated, happy, and healthy.

Shipping Time

"One hundred thousand roubles for the man who discovers a way of successfully shipping time."

This announcement was made by the English Parliament in the year 1714. And many people set to work at once on the difficult problem. Shipping time is not like shipping wine or pepper. You can't stow it away in the hold or put it into kegs.

Now don't imagine that the author of this truthful little book has suddenly gone out of his mind or that he is trying to make a fool of you. It is not only possible, it is absolutely necessary, to ship time.

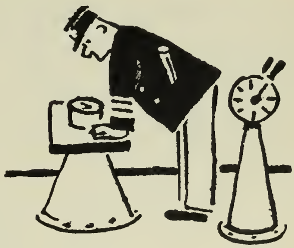
We all know that sailors have to determine their latitude and longitude at sea so as not to lose their course. Latitude is determined by the height of the North Star. The farther north the ship is the higher up in the sky this star will be.

But longitude, that is the distance from the first meridian, is determined in another way. Time is different on the different meridians. When the sun has just come up in Moscow, it is still night in London, because London is farther west than Moscow. The terrestrial globe, turning from west to east, has not yet brought London under the sun's rays. If at any given point it is twelve o'clock noon, then 15° west of this point it will be, not twelve, but eleven o'clock, 30° west it will be ten o'clock, etc.

$$15^\circ = 1 \text{ hour of time}$$

Therefore to determine longitude when travelling you must take a watch along and compare its time with the local time. If your watch is two hours ahead compared with the local time, this means that you have gone west 30°.

In the open sea, where there is no one about from whom you may ask the time, watches are tested by reference to the sun and stars. That's simple, isn't it? It looks as if it should be very easy. Just take your watch along, and that's all you'll need. Why give a prize for that?



It's not quite so simple as it sounds. A watch is, as you know, a capricious machine. It doesn't like to be jarred, and always suffers from seasickness on board ship. It loses and gains, so that it can't be trusted any more. For if the watch is one minute slow it will make an error of ¼° in calculating longitude. And that is a great deal. It might cause a ship to go out of its course and run on a reef.

So mariners have to carry a special, accurate timepiece called a chronometer. All the watchmakers in the world had been working for more than a hundred years trying to invent a chronometer, when suddenly two of them, an Englishman named Harrison and a Frenchman named Leroy, succeeded in doing it.

Harrison s chronometer made a successful voyage from Portsmouth to Yokohama on the ship *Deptford*. Shortly after this, the French frigate *Aurora* put out to sea with a still better chronometer, the work of Leroy. In a journey of forty-six days this chronometer lost only seven seconds.

As so often happens, Harrison got only part of the promised reward, and that only after a long fight.

Sky Clocks Again

There are no timepieces made which will never lose or gain. Changes in the weather, heat and cold, moisture, a chance jar or change of position, thickening of the lubricating oil—all these things slowly but surely interfere with the working of even the most accurate chronometer. If moisture, for instance, collects on the balance wheel, it becomes heavier, hence begins to oscillate more slowly, and the watch loses time.

A rise in the temperature affects a chronometer as surely as it does a thermometer. The spiral expands with the heat, becomes longer and weaker. This will then slow down the pace of the chronometer. In observatories, where accurate timepieces are kept, by which whole cities, countries even, regulate their time, the timepiece is treated as if it were a very delicate invalid. Careful nursing, complete quiet, in a word, it seems to be a sanatorium rather than an observatory, though such treatment would soon bring a human being to his grave. In Pulkov, for example, the clock is kept in the

cellar to protect it from sudden changes of temperature. People go to this cellar only to wind the clock, because even the proximity of a human body might affect its speed.

The clock at Pulkov observatory is connected by telegraph with the clock of Peter and Paul fortress in Leningrad. At 12 o'clock noon a cannon is fired from the breastworks of this fortress and the citizens of Leningrad, wherever they happen to be, stop work for a moment, take out their watches and set them by the booming cannon.

To-day correct time is also sent out by radio. The French were the first ones to do this, from the Eiffel Tower in Paris. Afterwards, radio stations all over the world followed their example. These radio signals go out in every direction, over land and sea, telling the citizens in their homes and the sailors on their ships what the correct time is.

But can we be sure that the most accurate timepiece never lies? Certainly not. We know that all watches lie, some more, others less. So again we have to go for help and guidance to those clocks which served mankind faithfully and reliably long before there were any clocks in the world, either wall clocks, pocket watches, or huge tower clocks. The sky clocks are the only chronometers which never, never lie.

The earth always makes its revolution in exactly the same length of time. The stars in their apparent movements across the dome of the sky always return to their positions in exactly the same length of time. It is only by the stars that we can correct our watches. That's why accurate timepieces are kept in astronomical observatories.

These sky clocks are still the only accurate and dependable ones. To-day, just as in those far-off days of the past, we are never deceived by the silent courses of the stars, undisturbed and unchangeable.

The Sky Clocks

The End

WHAT TIME IS IT?

The story of how people worked out various ways of telling time is one of the most fascinating stories in the world. Every now and then you will want to look up some of these topics and read about them again. When you do, this index will help you to find the right page.

CADMUS BOOKS