THE TYRANNY *of* TIME

Einstein or Bergson?

THE TYRANNY *of* TIME

Einstein or Bergson? *By* CHARLES NORDMANN *Translated from the French by* E. E. FOURNIER D'ALBE

T. FISHER UNWIN LTD
LONDON: ADELPHI TERRACE

(13)

16199/3639

104
N76T

First published in English 1925

115
N76T

INTRODUCTION

THIS volume comprises two distinct parts, intimately related to each other, and both concerning Time, our Master.

In the first part (Chapters I to V), the divisions of time imposed upon us by the movement of the Sun and the stars, which serve to cut up the daily course of events, the Hours, Days, Seasons, and Years, are analysed in the light of recent discoveries. We discuss the paradoxes of the calendar, and the strange *faux-pas* observed in the endless round of stars and hours. We finally describe the recent progress made by astronomers in the measurement and the wireless transmission of time.

This first part endeavours to avoid the didactic style, for we believe that neither dreams, nor even smiles, are incompatible with science. We do not hold with those who would not relieve the dryness of hard facts by flights of imagination. Must one be tiresome in order to be precise, and dogmatic to be instructive ?

In the second part of this book (Chapters VI and VII), which will appear somewhat more formidable, we plunge head downwards into a sea of controversy which at present separates two of the most famous men of our time, and which concerns the most fundamental question raised by science and philosophy. In resounding language, the illustrious philosopher Bergson has of late vigorously contested the relativity of time as demonstrated and affirmed by Einstein. He has been supported by eminent philosophers and by some physicists, who were led by Einstein's own premises, and by the facts he relies upon, to deny the relativity of time and to prove the existence of absolute time.

In this great debate between adversaries of absolutely opposite views, which fundamentally affects our ideas of the structure of the universe, who is right, Einstein or Bergson? That is what we endeavour to decide. The conclusions at which we arrive in this fascinating controversy are categorical. We shall see that none of our declarations are unsupported by evidence, and we shall profit by the occasion to clear up some minor points in the dispute concerning relativity.

Thus the reader will be in a position to judge of a debate which by its eternal interest infinitely surpasses our trivial political expediences and the frankly alimentary and pecuniary controversies in which we wallow every day.

By a curious caprice, the French language, different from others, designates by a single word, the word *temps*, two very different things: the time which goes by and the weather, or state of the atmosphere. This is one of the peculiarities which give to our language its hermetic elegance, its concentrated sobriety, its elliptic charm.

This book is devoted to the first meaning of *le temps*, and the other will only be brought in as an accessory. We wrote it because the problems raised by the measurement of time occupy more than ever before both the public and the men of science. This is probably due to the fact that modern society is a prey to two equally strong and yet contradictory passions. The first of these urges us to live and enjoy with a sort of trembling frenzy. The second makes us dispute and doubt everything and should logically lead us to inertia and immovable ataxy. When we delve into the essential notions of common sense we run the risk of finding nothing but vain appearances and the bitterness of disillusion.

Now this numbering of the durations which mark our frail existences has the privilege of touching upon the impervious necessities of practical life on the one hand, and the highest peaks of philosophy on the other hand. *Time is Money* and *Does Time exist?* are formulæ which might symbolise the two opposite aspects of the problem, both equally urgent. Hence this book.

Between the ever-growing uncertainty concerning the very existence of time on the one hand, and the ever-increasing precision of its measurement on the other hand, the contrast has some of that flavour of melancholy which pleases our modern taste.

"Oh Time, delay thy flight!" sighed Lamartine. But the flight referred to by that great and lanky poet who never smiled, is not the flight La Fontaine had in view when he called time the "notorious robber." La Fontaine's smile is perhaps more proud and stoical than Lamartine's despair. Prometheus on his rock needed but one thing to make him superior to the gods who tortured him: to laugh in their faces.

To reflect on time means to think of death. Philosophy is but an epitaph. But is it not this contact with the void which gives to life its rarest charm?

The Masters of the Hour are not the "great men" of this little Earth, who believe that they are guiding men, but who are guided by things. The real masters are the thinkers and *savants*, those frock-coated priests who guard the temple of time and analyse, determine, and conserve the hour. From the former to the latter the way is an ascending one. Charles the Fifth, the unrivalled master of earthly power, understood that well when he found but one step more to take: to become a clockmaker.

What rule of life can we derive from the ephemeral character of all things, emphasised by the study of time? There is the rule of the Latin poet: "Live as if you were to die to-morrow." With equal force one could uphold the opposite: "Live as if you were never to die." I believe that wisdom would lie in this: "Think as if you were to die to-morrow, but act as if you were to live for ever."

But nothing can equal the bitter sweetness of dreaming on the banks of Time, that impalpable and fatal river strewn with dead leaves, our wistful hours carried down stream like rudderless wrecks.

CHARLES NORDMANN.

CONTENTS

FIRST PART

CHAPTER I

CHAPTER V

THE MASTERS OF TIME AT WORK

SECOND PART

CHAPTER VI

EINSTEIN OR BERGSON?

CHAPTER VII

STRANGE CONSEQUENCES OF THE RELATIVITY OF TIME

FIRST PART

CHAPTER I

THE HOUR-GLASS

Old Chronos—Time and eternity—Non-existence of Time to the Perfect Being—Sirius and the vague year—Cæsar imitates the Egyptians—Science and platonic affection—The sun's path along the Zodiac among the equinoxes and solstices.

How easy and simple everything was in the luminous days of Pagan Greece! There was no Mystery, no Unknown; every phenomenon was explained at will. A thunderclap? It was Zeus knitting his eyebrows. The storm lashing the blue Ionian Sea? Hephæstus, riding in an emerald shell drawn by a team of sirens and glittering tritons, had unchained it with a stroke of his masterful trident. Did the earth tremble? It was but the effect of quarrels which, in the Underworld, relieved the monotonous conjugal life of Aphrodite and her limping husband. The slopes of Olympus were peopled with gods and demigods who shared the duties of producing the phenomena of nature. These divine personages furnished plugs for filling all the gaps of discontinuity in human knowledge. They left no insoluble problems or embarrassing questions.

Had you asked a wealthy citizen of Athens or a cobbler in a booth under the shadow of the Parthenon, what he understood by Time, he would have replied that it was a thin muscular old man standing between a formidable scythe and a slim hour-glass, who presided over the daily course of our miserable destinies. Old Chronos is figured like that even in modern engravings.

Yet even in those days philosophers, brooding over the Unknown, had conceived other ideas, which we have hardly yet surpassed. After profound reflection, Aristotle declares that time was "the number relating to movement when the latter is considered as having a preceding and a succeeding portion."

The great Laplace, twenty-two centuries later, gave a definition which differs but slightly from that of the Stagirite. "Time," he said, "is to us the impression left upon our memory by a series of events whose existence we know to have been successive."

But perhaps I was mistaken in supposing that the ideas of the ancient Greeks concerning time were childish. Perhaps there is no great difference between the ideas of a cobbler or merchant of the time of Pericles and those of a conscientious voter of the Clignancourt quarter. Perhaps, also, there is no great difference between the conceptions of an Aristotle or Plato and that of an Einstein or Bergson. It may be that in the domain of pure reason, in the domain of the "thinkable," there is less progress in the strata of the centuries than there is at any one time in passing from the brains of the vulgar to those of the eminent.

What gives an Einstein or a Bergson a superiority over their ancient predecessors is that they know facts and have made experiments unknown to the latter. Our physical ideas of time, on the other hand, have decidedly advanced since they have profited by the results of all the experiments carried out since then, and all the new facts placed in evidence. "Experience," says Poincaré, "is the only source of truth." It is the only source of progress in truth, I mean controllable truth, not metaphysical or mystical truth, which have the good fortune of passing over and outside those spheres where sense experience crawls on its prosaic way.

Before, therefore, we can examine what time, real time, is in reality, what it is that we see passing, or which sees us pass, we must first recapitulate the facts, the phenomena, and the measurements which have gradually revealed to us its fleeting and deceptive form.

When Leconte de Lisle exclaimed in his pathetic invocation :

> "Oh Death divine, claiming and saving all,
> Deliver us from Time,"

he emphasised the fact that time, or what we call such, does not exist and is inconceivable except to him who is ephemeral. Whether we deal with the psychological time so acutely studied by M. Bergson, which is the feeling of the flow of things ; or physical time, the measurable time of science, these two times are only modalities of each other. They have one thing in common. A single characteristic (whether of sensations or perceptions) distinguishes for us a present thing from a past thing : It is that the latter is less vivid, less precise, that, as Poincaré has shown in a famous writing, we have lost the sense of its complexity. For an infinitely perfect Being like a God, past sensations would be as vivid as present ones, and time would no longer exist. This has been deeply comprehended by theology, which distinguishes and separates time from eternity.

But if we can conceive above men an infinitely perfect Being for whom time would not exist, we might be expected to conceive below them a state in which time would be equally non-existent, a state of Nothingness or Death. In a universe without motion, or, more generally, without change, without differentiation, and without the succession of heterogeneous states, there would be no time.

Thus, midway between an infinitely perfect state and nothing, both of which imply the non-existence of time, the latter is the characteristic privilege of mortal beings and ephemeral things, both animate and inanimate.

To put it briefly in the language of algebra, the variation and differentiation which characterise life are functions of a variable which we call Time.

When we, therefore, apply measures and figures to mobile phenomena in a manner which characterises them and their background, we are measuring time.

From the beginning of humanity, and indeed from the beginning of life—for animals also often model their habits to the periodicity of day and night—the succession of night and day has furnished a natural and convenient division of time, a division which, in the nature of things, is most frequently used.

Men soon noticed that the number of successive and similar events which could take place in a day, that is, between two successive passages of the sun through the height of the heavens, remained nearly constant. The period elapsing between two such culminations is called a "day." They found, for instance, that the distance a man could cover or the quantity of material he could transport between two given points remained the same for that interval.

They concluded from this, more or less consciously, that the time elapsing between two successive passages of the sun through its highest point in the sky remains the same, and they adopted that interval as a measure. Even now, as we shall see, that primitive unit is the one we use in the most precise measurements. We shall also have to enquire up to what point it is really invariable. We shall do that when we study the hour.

For the present it suffices us to know that the *hour*, as employed and defined to-day, is the twenty-fourth part of the "mean day." It is, in fact, the duration of the year divided by 365×24, or by 366×24 in leap years.

The Greeks called this complete day *nycthemera*, literally night-and-day. For the moment, we shall only consider the day as a divisor and not as a dividend. We shall see how men are brought to join or group a certain number of days into more extended units of time.

The ancients, and particularly those who, like the Egyptians, were agriculturists, noticed from the beginning that after a certain number of days the same phenomena occurred in vegetation, and that the highest point attained by the sun in its daily journey varied periodically in such a way that the same seasons and the same phenomena of vegetation coincided with identical heights of the sun. Thus was born the idea of the year, which embraces and contains the totality of these periodic and parallel events.

It seems proved from hieroglyphic documents going back to the 12th dynasty (3000 B.C.) that the Egyptians even at the distant epoch knew that the length of the year is 365¼ days. They owed that fundamental knowledge to the regularity with which a certain local phenomenon of great importance to them recurred every year, viz. the rising of the Nile. They also noticed from the beginning of their civilisation that the annual flooding of the Nile valley took place when the most beautiful star of the heavens, Sirius—they called it Sothis—rises at the same time as the sun.

Thus, beside their civil year of 365 days, which they called the "vague year," they used for their agricultural works the year of 365¼ days, defined as the interval between two successive "heliacal" risings of the beautiful Sothis for the latitude of Memphis. Adding up 1,460 quarters of days we get a total of 365 days. It follows that at the end of 1,460 years of 365 days each, the heliacal rising of Sirius would occur on the same date. Hence the name Sothiac Period given by the Egyptians to that period of 1,460 years which brings into coincidence the beginnings of the civil year of 365 days and the agricultural year of 365¼ days.

The Chaldæans, and afterwards the Greeks, successively borrowed from the Egyptians the year of 365¼ days, which the latter had the incontestable merit of discovering. As regards the Romans, who were much more warlike than scientific—one cannot be everything—they did not at first profit by that fine discovery, of which they were ignorant. Their year presented incoherences and absurdities which need not be described here. They brought about much disorder until Julius Cæsar, by a great act of dictatorship, introduced his famous reform of the Roman calendar, went back to the Egyptian tradition, and made an end of the irregularities which placed the civil year out of all relation to the seasons.

Such, in rough outline, was the evolution, occasionally retrograde, from learned Egypt to barbarous Rome, which brought the year we still use up to the Christian era.

To-day we know that the purely local, agricultural, and practical data which had taught the Egyptians the duration of the solar year with such marvellous accuracy, have their counterpart in other data of a purely astronomical kind, which are independent of all geographical contingencies.

These astronomical data are, on the one hand, derived from the earth's rotation on its axis, and, on the other hand, from its revolution round the sun. In other words, they are obtained from the apparent daily revolution of the sun and its annual movement among the constellations. The question of knowing whether the earth *really* turns round the sun, or the contrary, has nothing to do with the accuracy of the calendar, and the latter does not in any way concern the question of the prosecution of Galileo.[1]

Just as the Egyptians had noticed that the heliacal rising of Sirius recurred after about 365 days, the Chaldæans observed from the earliest times that the heliacal risings of certain other stars recurred regularly after that same interval. They counted the time by means of twelve lunar months or durations. The month being originally defined by the return of the same phases of the moon, the twelve lunations amounted to 354 days. In order to produce an agreement with the agricultural seasons, they had occasionally to add an extra thirteenth month to their year. This explains the following inscription found on a Babylonian tablet now in the British Museum: "The star Dilgan, the star in the head of the constellation of the Ram, makes its heliacal rising in the month of Nisannu. Every time this star remains invisible, let its month be omitted."

This prescription is repeated for the chief stars of all the other months. It followed that when the star characteristic of a month remained invisible during that month, that month retained its name, but was

[1] In a recent book (*The Kingdom of the Heavens*, Chapter VI) I have examined in detail the question whether the earth turns. Classical science seemed to have settled that question, but Relativity has raised it again quite unexpectedly.

not counted among the twelve months of the year, and played the part of an intercalary month.

Nothing could more clearly exhibit the high perfection already attained by Babylonian astronomy, in practice at least. For those people of Asia cared nothing for astronomy considered as a branch of pure knowledge, like a precious liqueur suitable for quenching our intense *libido sciendi.* The glory of having thought of that, and of having placed that ideal above all the miserable contingencies of utility, belongs to Hellas. Without her we might have had practical formulæ, perhaps even astonishing machines and industries. But Science, that great platonic affection, would have been unknown.

Following the Egyptians and the Chaldæans, the apparent positions of the sun among the stars were determined with ever-growing precision. It was found that the fixed-figures made by the stars in the night sky reappeared at the same seasons. It is always in winter that Orion shines with his belt of carbuncles, and in summer that Arcturus twinkles red in the zenith and the Lyre sheds the sapphire rays of Vega.

And since nimble thought can clear at a bound all the stages which, through the mists of history, have led our knowledge up to its present height, let me say in a few words, necessarily somewhat dry, what we know about these things to-day :

The sun, in its apparent annual course among the stars, crosses in succession the twelve regions of the sky which form what are called the "signs of the zodiac." These regions approximately coincide with the constellations from which they are named, viz. the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Balance, the Scorpion, the Arrowman, the Capricorn, the Waterman, and the Fishes.

The line which the sun thus seems to describe among the stars, and which is called the Ecliptic, is a great circle passing right round the heavens. Now let us imagine a plane, like an infinitely thin and infinitely wide blade cutting a fruit, which should cut our terrestrial globe in half along the equator, so that our northern hemisphere should be on one side, and the southern hemisphere on the other side. That great plane would cut the starry vault along a great circle concentric with the earth's equator, and that circle is called the celestial equator. On both sides of the celestial equator, the stars have unvarying positions, just as the various towns on earth have latitudes which do not vary with respect to our equator. This is due to the fact that the whole of the stars seem to turn *en bloc* round the line of celestial poles, a line which forms a continuation of the earth's axis, round which the earth turns (or appears to turn).

Now if we find the positions occupied by the sun at different times of the year along the ecliptic, we shall see that the sun is sometimes above and sometimes below the plane containing both the earth's equator and the celestial equator. In summer it is above it, and in winter below it. In the summer, the sun is in the northern hemisphere of the sky and favours our northern races with its rays. In the winter the case is reversed. It passes high in southern skies and low in the sky of us poor Hyperboreans. The instant at which the sun, coming from the south, traverses the celestial equator to penetrate into the northern celestial hemisphere fixes what is called the "spring equinox" or vernal equinox. On the other hand, the instant when the sun, at the end of our summer, traverses the celestial equator on its way to the south is called the "autumnal equinox."

Between the vernal equinox and the autumnal equinox there is a moment when the sun in its course among the constellations reaches its greatest northerly position above the equator. That moment when the sun, while still in our hemisphere, commences to decline towards the south is called the "summer solstice." Similarly, there is a moment in our winter when the sun attains its greatest declination towards the south, and begins to mount towards the northern constellations : That moment is the "winter solstice."

CHAPTER II

ANOMALIES OF THE SEASONS AND DAYS

Several sorts of years—From Magellan to Phileas Phog—The sunniest day and the longest day of the year are in winter—Seasons and climates—Leap year proposals—The equinoctial paradox—The Convention, Vendémiaire, and the real beginning of the year—Christmas, the baptism of the sun.

AND now, armed with these didactic particulars—tiresome but necessary—we may know with precision and security the year and the twining round of its daughters, the seasons.

May I be pardoned the aridity of these definitions and data. But before we play a symphony we must learn to play scales. Before tasting the savoury profundities of a Racine or Baudelaire, we must learn to spell and to read. Nature herself does not yield up her marvels and mysteries without a mild lesson in the prosaic school of technical knowledge.

The year, such as everybody understands it in practice and such as the ancients endeavoured to measure it, is the interval of time which separates the returns of the same seasons. It is the interval between two occurrences of the vernal equinox.

Astronomical observations have established the fact that this interval is at present 365·24219879 days, which amounts to 365 days, 5 hours, 48 minutes, 45 seconds, and 98 hundredths of a second.

The above number represents the duration of the year in 1900. Experience has shown—we shall return to this very important point—that the duration of the year diminishes by 53 hundredths of a second, or a little more than half a second, in the course of every century. Thus, in 1924, the duration of the year is 365 days, 5 hours, 48 minutes, and 45·86 seconds. These twelve hundredths of a second by which the year has shortened since 1900 look like nothing at all, and indeed they produce no striking effect among the people to whom time is nothing but money. We shall see that, on the other hand, in the eyes of philosophy—and what eyes are more worthy of respect and admiration, unless those of beauty ?—this minute difference is rich in astonishing consequences.

The year as defined above—the interval between two successive vernal equinoxes—is what astronomers in their esoteric language call the *tropical year*.

Are there other sorts of years ? Yes. There is the year which at the Observatory we call the "sidereal year." It is the time required by the sun for describing a complete circuit among the stars, in other words, for tracing in the heavens an arc of 360°. But is not that the same time as the interval between two vernal equinoxes? It would be so if the vernal point or equinoctial point were fixed among the stars. But that is not the case, owing to a singular phenomenon which is called the Precession of the Equinoxes. We cannot here attempt to explain this precession. We only need know that it is caused by the moon. Yet another lunar influence unsung by Baudelaire.

While the sun in its annual course advances majestically among the stars, the equinoctial point slightly moves in the opposite direction, so that when the sun reaches that point again it has in fact made a little less than a complete circuit.

The sidereal year is, therefore, a little longer than the tropical year, the difference being over 20 minutes.

There is yet another year defined by astronomers. It is called the *anomalistic year*, or the time elapsing between two successive passages of the sun over the point nearest the earth, which is called the *perigee*. The sun does not describe a circle round the earth, but an elongated curve which brings it nearer or farther away. Or if to this geocentric mode of expression one prefers the Copernican language we shall say that the earth in its annual course round the sun approaches the latter now more, now less, and is nearest to it at the moment of *perihelion*.

The anomalistic year, or the interval between two successive perihelia of the earth would, of course, be equal to the sidereal year if the perihelion always found the same point in the starry vault. But it is not the case. The earth's perihelion has a proper motion among the stars, like the perihelion of Mercury, so perfectly explained by Einstein. It follows that the anomalistic year is a little longer than the sidereal year. It actually lasts 365 days, 6 hours, 13 minutes, 53 seconds, and a fraction.

There is a fourth sort of year also, called the *civil year*. It is used by men in practice, even by astronomers, and consists of an exact number of days, 365 in ordinary years and 366 in leap years.

In what follows we shall only concern ourselves with the civil year and the tropical year. And that will be quite enough.

Civilised people, or those presumed to be such, are at present in the habit of commencing the civil year on the first of January. It is an occasion of festivals, presents, and mutual greetings.

Nearly all over the globe, and even in some parts of France, the habit of indiscriminate kissing has survived in the night from the 31st of December to the 1st of January, to mark the solemn moment when the New Year emerges, like a butterfly, from the chrysalis of the old year. We may as well honour this tradition, all the more agreeable, in spite of the kill-joys, because there are plenty of fresh cheeks in the world. It makes the atmosphere in which the new year is born fragrant with the mixture of vanishing powder and *marrons glacés.*

But let us examine it more closely. The instant which marks the birth of the new year and which leads people to a labial communion in the same emotion, is it as definite as is ordinarily believed? I am afraid not, for, as we shall see, that fateful instant is not only conventional but variable and contingent.

In Central Europe the year commences an hour before it does in France, while in America it commences some hours later, since the hour advances regularly and the sun rises earlier as we proceed from west to east.

We must therefore find when the new year actually commences.

If a traveller goes round the world from east to west, and sets his watch by the sun, or, which comes to the same thing, by the network of hour sectors he traverses, he will see the sun rise once less often than he would have done had he stayed at home. If no compassionate person were to help him out of this difficulty on the way his diary will, on his arrival home, be one day behind the calendar he finds at home. That is precisely what happened, to their great astonishment, to the companions of Magellan during their celebrated circumnavigation of the globe.

Starting from Europe towards the west on the 20th of September, 1519, they arrived home on the 7th of September, 1522, whereas their ship's log only showed the 6th of September. If, on the other hand, we travel round from west to east, we arrive home after living through a day more than the people who did not leave home. That is what happened to a traveller nearly as celebrated as Magellan, Phileas Phog, and it enabled him to win a wager he had considered lost.

To avoid these difficulties, the following convention has been adopted: When a navigator passes through the meridian at the antipodes of Greenwich, that is, the meridian of 180°, he puts down in his log two successive days of the same date if he travels from west to east. If he travels in the opposite direction he skips a day. This is necessary. For let us suppose that in the night which for us is between the 20th and 21st of August, let us say, and at what is midnight to us, a vessel touches the antipodean meridian coming from the west. To him it will be midday of 21st August. If another vessel reaches the same meridian from the opposite direction, his log will then show noon of 20th August. Fortunately, the 180th meridian mostly traverses oceanic regions with little population. Yet, in practice, the "date-changing line" deviates slightly from the meridian in some places. Thus, an exception had to be made in order to link up the extreme point of Kamchatka with Siberia, and the Aleutian Islands with Alaska. But a paradoxical result is obtained inasmuch as a given day commencing on the point of Kamchatka is behindhand in date with regard to the same day on the Aleutian Islands, though the sun rises earlier in Kamchatka.

Thus, over a wide area of the globe, the month of February may have 30 days in leap year! Or only 27 days in ordinary years, depending upon whether it adjoins these regions on the west or the east. And this shows clearly that the anniversaries which we are pleased to surround with such touching and useless solemnities correspond to nothing conventional. As regards the present year, it will be seen that it commenced on earth when it was midnight on the 180th meridian. At the moment our clocks in France showed noon, 31st December. The traditional embracings were, therefore, ill-timed and premature.

The usage of commencing the year on the 1st of January dates from Charles IX. Before his time it commenced at Easter. When, in the eighteenth century, an identical reform was made by Lord Chesterfield in England and it was decided that the 1st of January 1751 should be dated 1752, there was a riot and the noble lord was nearly cut to pieces to the cry of: "Give us back our three months!" It was a fine and imposing labour demonstration.

Yet the woman of Fate who cuts the thread of things, had she leisure to lift her face from her scissors, would smile. She knows that the flight of time depends no more upon the measure employed than our height does upon the yard-stick.

By the side of the people who joyously celebrate the 1st of January and look ahead, there are others, more reasoning but less wise, for whom this date means the melancholy end of all that the past year has taken away. These are the people whose timid steps tremble at every anniversary on the way to the grave.

But by and by, when man will have become reasonable—it cannot be longer than some thousands of years—he will be free from these childish sorrows. The need of the peace of death will come to him in his declining years. As my master, M. Dastre, says so beautifully, it will be like the desire for sleep at the end of an arduous day.

From the time of its birth (in 1924 it was 2 a.m. on 2nd January) January brings us year by year a curious phenomenon in its frosted hamper.

On that day the inhabitants of our regions, and especially the Parisians, wade about in an icy mud and are entertained with fog, sleet, melting snow, and most often that rain to which they are accustomed and which recalls the time when Gargantua, from the height of Notre Dame, soused them and drowned 260,478 men, not counting women and children.

Yet in reality New Year's Day, as we shall see, is the sunniest of all days. That seems a paradox. But are there not many truths which are usually held to be paradoxes ?

When winter reigns in Europe it is due, as everyone knows, to the inclination of the earth's axis towards the plane of the ecliptic, which produces at the same time the hot season in the southern hemisphere. Let us forget for a moment our little northern prejudices, and let us place ourselves in the point of view of the earth as a whole, limited as it is. The earth describes round the sun not a circle, but an ellipse in which the sun is placed eccentrically. Now the orientation of that ellipse is such that in the first days of January we are in perihelion, that is, at our shortest annual distance from the sun, about 91,500,000 miles; whereas, six months earlier, when the sun was farthest away, it was approximately 95,000,000 miles away. It follows from all this that on the day in January which marks the earth's perihelion we also receive the greatest amount of solar heat. It has been computed that the earth receives 10 per cent. more heat at that time than it does at the beginning of July.

This eccentricity of the earth's annual orbit has some very curious results. Since the northern hemisphere has its winter at the time when the sun is nearest, and the southern hemisphere has its winter when it is farthest away, the southern winter must be more severe, and its summer must be hotter, other things being equal. That is one of the causes which make the climate of the northern hemisphere more temperate, on the whole, than that of the southern hemisphere.

I once happened to speak slightingly of the sun because it was a small thing from the point of view of Sirius. It is true, and yet I was wrong, for we should know nothing of Sirius without the sun, because we should not exist at all.

Its beneficent rays are the golden net which suspends terrestrial life over the void. And all men who know it feel themselves as sun-worshippers, especially when the first snows place their woolly festoons on the bare branches of the trees.

The sun is truly the father of all that breathes here below, and some day, no doubt, the United States of the planet earth will choose for their national festival the day when it is nearest to us, that is, the 2nd of January.

Under various forms the sun has indeed been worshipped from the earliest times. He was Adonis, whose awakening put the red colour into the cheeks of maidens. He was Osiris and the splendid Indra. He was Apollo, the father of the Muses, and of

Æsculapius—a remarkable anticipation of the modern sun-cure. But he was also the ferocious god of the Incas, and Baal, and Moloch, spattered with blood and human sacrifices, as if the colour of the purple sunset did not suffice for his glory! It is only too true that in personifying even the most magnificent symbols men have an invincible tendency to conceal all their pettiness under their cover.

We ourselves might be inclined to raise suppliant hands towards the sun, but for the fact that they hold spectroscopes wherewith to examine him.

The first burst of truth sometimes partakes of a scandal. The sun's volume is 1,280,000 times the volume of the earth. Yet when Aristarchus of Samos dared to say that the sun was larger than the Peloponnesus he was accused of impiety. The fools, who were many even in those days, regarded him as a malefactor, and the moderate people took him for a madman fit to be interned in the Athenian substitute for Bedlam.

Yet I imagine that the poor wretches who bend a shivering back to the penetrating blast of Nivose will not feel any warmer on learning by chance that January is the month when the terraqueous globe receives most heat from the sun. Our reason may sometimes give us the illusion of a general view of things, but our sensations are centred in ourselves.

We do not feel winter the less for knowing that it is hot in Patagonia.

Yet there are people who have been deploring its disappearance.

Mr. Winter of the snowy beard and the icy breath is a pleasing figure when seen through the windows of a well-warmed home. For some years he seemed to be dead, to have disappeared nobody knew whither. None of the telegrams despatched by those aerial policemen whom we call meteorologists reported him anywhere. What has become of him? The Lost Property Office at the Prefecture knows nothing, and wherever central heating makes an agreeable climate in the drawing-rooms, elderly people of both sexes lament the disappearance of the seasons and deplore the levelling tendency which, passing from man to the seasons, seems about to reduce them to the same dead level of mediocrity.

But in reality the meteorological averages, which do not indulge in sentiment, prove that our climate hardly varies at all, and we may still expect hard winters from time to time.

On the other hand, we must not be scared at the degrees by which the thermometer may fall below freezing point, especially in France. A minimum of 31° centigrade below zero (—24° F.) was recently observed in the east of France. But that is still very far from the lowest temperature observed since man exists and uses a thermometer. At Verkoyansk, in Siberia, a temperature of −112° F. has been observed. There must be much harder frosts near the South Pole, since Amundsen, at 620 miles from the pole, observed a mean annual temperature of −13° F. Even that is but a trifle compared with the conditions which obtain on some of the other planets. We may be sure, indeed, that on Mars the mean temperature must be some 72° F. below that of the earth, on Saturn 324° F., and on Neptune about 400° F. (220° C.). If some magician were to transport our earth to those regions, not only would the water congeal, but the air itself would freeze, and cascades of oxygen and nitrogen would fall noisily from rocks of solid carbonic acid.[1] And the beauty of the landscape would be considerably enhanced by the fact that there would be no biped artists to caricature it and exhibit it at some autumn *salon*.

Long ago it was much colder than it is now. The moraines and erratic blocks found everywhere are silent witnesses of the time when the whole of France was an immense glacier such as Greenland is to-day, where nothing but the starry hexagons of fresh snow could bloom. Numerous and various hypotheses have been put forward to explain this glacial period, and we cannot consider them here. Hypotheses, if I may say so, are to men of science what promises

[1] This assumes a considerable compression of those gases.—Tr.

are to a politician: they are useful and convenient to him who makes them, so long as he does not attach too much importance to them, but makes use of them and forgets them as the occasion may require.

What is more serious is that geologists learnedly assure us that we may very well enter another such glacial period. We shiver at the thought. But let us take courage, it will not be very soon. Geological periods last tens of millions of years, and we can make our arrangements for those formidable winters of the future. If the mean temperature of the earth changes, it does so very slowly, and it can be shown that it has not varied by a degree for 2,000 years. This results from a study of the cultivation of various plants, and of the silkworm in China. At Athens to-day, as in the days of Aristotle, the date palm puts forth flowers and fruit, but does not ripen. Were the temperature but one degree higher, it would ripen. If it were one degree lower, no fruit would form. If, therefore, the earth's climate varies, it does so without haste, and the small variations perceived from year to year have always existed since history began, and have merged in the great law of averages. These slight variations have one great advantage. They furnish a protest and a cause for grumbling and complaining such as forms the foremost characteristic of human animals. In this respect, the initial jerk which inclined the axis of the terrestrial top by a quarter of a right angle to the ecliptic was providential, since it gave us the seasons and its small crises, perennial sources of trite conversation among people who have nothing to say to each other.

Let us therefore enjoy by the fire those mellow delights which the winter brings to chilly souls and bodies. And let us appreciate the delicious humour of the language which calls the coldest days the "heart" of winter.

The month of February with its 28 days, sometimes expanded to 29, brings back our thoughts to more truly chronological subjects. And if the months have any influence on the course of our reflections, which is by no means certain, February is the month most likely to bring home to us the difficulties attending the measurement of time. The latter relentlessly pushes us towards that couch where

"Death, like a mother, shall kiss
Our brow and chase away
The troubles of the day."

Yet this equalitarian grave-digger interests us, and while he hangs about our shoulders we like to watch his changing and deceptive aspects out of the corner of our eye.

Thus the Bourgeois Gentilhomme, who made up in common sense what he lacked in spirit (whereby he showed himself more bourgeois than gentleman) wanted his teacher of philosophy to "teach him the almanac." How many of those who find this idea of M. Jourdain's comical would not be considerably embarrassed if the most elementary questions were addressed to them on this subject?

M. Jourdain's request was reasonable. His chubby soul had guessed that the explanation of the almanac touches upon the most delicate points of physics and metaphysics, and that it also touches history at some points, as well as religion and other things too numerous to mention.

Julius Cæsar deserves the credit of having put some order into the measurement of time, which among the Romans, those great civilisers, depended until then chiefly upon the good pleasure and the esoteric fancies of the Pontifex Maximus. From that time onwards, astronomers knew that the tropical year, that is the time elapsing between two passages of the sun through the same equinox, is about 365¼ days. In order to allow for this quarter of a day, Cæsar decided that every set of three years of 365 days each should be followed by one year of 366 days.

But in reality the tropical year is not really equal to 365 days and 6 hours. It is less than that by about 11 minutes and a quarter, as we have seen, which would mean that the Julian calendar would be slow by one day in every 128 years as compared with the sun. It was in order to allow for this fact that Pope Gregory XIII at the end of the sixteenth century proposed the reform which governs our present calendar. Since there were too many leap years in the old calendar, three of them were suppressed every 400 years, and it was agreed that the century years whose first two figures were not divisible by four, such as 1700, 1800, and 1900, should not be leap years. The year 2000, will, however, be a leap year. The Gregorian reform is so successful that there will be no difference amounting to a day between the astronomical and civil year for 3,000 years. If the Julian calendar, still employed in some parts of Eastern Europe, differs from ours by 13 days (it was 12 days before 1900) it is because Gregory XIII made his reform retrospective and made it date from the Nicene Council (A.D. 325).

The Protestant countries hesitated for some time before adopting the Gregorian calendar. They preferred to disagree with the sun rather than obey the Pontifex whom Luther, with some exaggeration, described as the Antichrist. Some orthodox countries still use the Julian calendar. Some of them believe themselves to be 13 days behind civilised Europe, while, if wicked tongues are to be trusted, they are really 13 centuries behind.

We shall refer to this again when discussing the reform of the calendar.

March, in spite of its martial and non-bucolic name, is the month which brings back the springtime.

The sun, in mounting northwards, crosses the celestial equator about the 21st of March. But it is not always the 21st as is currently believed, owing to some ancient edicts of Church Councils. In 1924 it is on the 20th of March at 21 hours, 20 minutes, 14 seconds of Greenwich time. In 1925 it will be again on the 21st.

At the precise instant fixed by the Nautical Almanac, that official programme of celestial festivals, stern winter hands over the reins of government to genial spring.

No official ceremony loaded with tiresome public speeches celebrates this transfer of power, no black or coloured robes are taken from their storage places. But in the absence of solemn functions the joyous event stirs many hearts, and I am sure that on that day, on the lawn of some beautiful garden—perhaps the Luxembourg Gardens or the Parc Monceau (I am not versed in the secrets of goddesses)—the three graces give tender, delicious, and laughter-loving spring an appropriate welcome.

As regards the equinox itself—that celestial Beadle of the new season—it is the instant when the sun is at precisely the same distance from both celestial poles. Treatises on astronomy, in complicity with faulty etymology, assure us learnedly that it is the only moment when day is equal to night all over the earth. Now that opinion, however familiar and classical, is not exact, and we shall see that, on the contrary, the equinox is the only moment when the day is not equal to the night anywhere on earth.

This is due to a property of our atmosphere which we call refraction. Who has not noticed that, when we watch the sunset from a hill, the radiant disc, on approaching the horizon, seems to flatten out like a gigantic orange? That is because its rays then traverse our atmosphere where it is thickest. It deflects the rays as would a glass prism, so that the sun appears higher than it is in reality, the effect being more pronounced at the lower edge. The result is that while the sun is really below the horizon we still see the whole of it. It therefore rises earlier and sets later than it would without the atmosphere. At Paris, for instance, this gives us 48 extra hours of sunlight every year. The classical definition of the equinox is only exact on the supposition that our earth has no atmosphere. At the equinox, therefore, the day is a little longer than the night all over the globe. At any other time of the year there is some latitude where day and night are equal. Apart from the equinox, there is always a hemisphere in which day exceeds night, and another where night exceeds day, so that in some intermediate region near the equator they are equally long. And that proves our paradox. Q.E.D.

Thus in science there are dozens of so-called truths which are not discussed, and which are false. Outside science there are thousands.

Fortunately, and in spite of its false name, the equinox is observed in the orchards and the meadows, which spring fills with sweet enchantment. Punctually, in its honour, the golden primroses and the pink apple blossoms open their delicate petals to tinkle their carillon, which is but a perfumed silence.

The instant of the equinox is not fixed. Every year it "precedes" its predecessor. This Precession of the equinoxes, caused by the attraction of the moon, is very slow, and it takes 26,000 years to make a complete circuit of the ecliptic. It has some curious consequences. The first of these is that the duration of the seasons changes constantly. At the present time, spring lasts 92 days, 20 hours. Its length, added to that of summer, exceeds the length of autumn and winter together by 8 days. In A.D. 1250 the former seasons lasted 36 days longer than the latter. It follows that the northern hemisphere has a week more of the presence of the sun than the southern hemisphere.

I can imagine some enthusiastic sun-worshipper drawing vast conclusions from this. He might argue, with all the force of a Sorbonne thesis, that this is the cause of human civilisation centring in the northern hemisphere of this little planet, the daughter of the sun. But one must beware of seeing cause and effect in this, for 10,500 years ago, and owing to this same precession, it was the southern hemisphere which had 8 days more of the sun than ours. Besides, all this is very ancient, and I do not care if I am told what the weather was when the animals spoke. And are we sure they speak no longer ?

Another result of Precession is that the celestial pole is constantly changing its position. In 13,000 years the Pole Star will be 45° from the pole, and Vega will be the new Pole Star.

Thus nothing is constant in the universe. The stars we call "fixed" are really the travellers of the heavens. The sun, with a speed of 50,000 miles an hour, is going God knows where. The poles, the ecliptic, and the whole world which we used to consider as of a marble immobility, are dancing a fantastic dance. But it is just this mobility, change, and diversity which make the conflict and the very life of things. Charles V, who all his life had the fixed idea of unity, a chimera of an emperor and city builder, who made war for forty years to unify the world, had not understood this even when, tired of vanities and alone in his monastery, he tried to keep some dozens of watches in agreement. Yet one day, when his valet had carelessly dropped his table full of socialised watches, Charles made the profound remark : " Absolute agreement is decidedly impossible except in immobility." He had found it out at last, and that is not bad for an emperor.

But March does not only bring us spring in his wet arms. He also brings hail-showers always and Easter sometimes. Here also he belies his formidable warlike name. With his continued alternations of showers and fair weather, his garment of rainbow hues, is he not the very image of the delightful versatility of woman ? And when the calendar is reformed—there is nothing men will not reform, except themselves—I propose to substitute the name of Venus for that of Mars in the appellation of this month. It will be more suitable.

We must never look for common sense in the calendar. We should only be disillusioned. If ever some Newton finds logic in any human institution—it may happen about the time of the squaring of the circle—it will not be in the calendar. For instance, the republican calendar, of which we shall have more to say, and which, whatever one may think, was the most rational attempt ever made to subdivide the year, called February *Pluviose*. Now our meteorological reports establish the fact that February is the month of least rainfall in our regions. In Paris, February has 50 per cent. less rainfall than May, June, July, August, or September. As regards March, the convention had called it *Ventose*, which is fairly right. But if the small rains beat down the great wind—and hail-showers are small rains—the wisdom of nations does not emerge with credit. Truly, the Goddess of Reason is not reigning yet.

What is the cause of these rains? It is clearly the evaporation of the waters of the ocean under the influence of the sun's rays and the wind. But what we have only known for a short time is that radium has a preponderating influence in the condensation of atmospheric moisture into rain. It has been established, in fact, that saturated water vapour condenses round the small electrified centres called "ions," and that radioactive substances contained in the soil produce these ions by bombarding the air with their rays. This is the more remarkable since the earth contains only about a millionth of an ounce of these substances per pound of soil, and yet it is true. It is also known that this condensation of rain takes place on dust particles in the atmosphere, which behave like "ions." Hence the clearness of the air after showers. Contrary to current opinion, rain-water collected in cisterns is not distilled water. It must always be filtered or boiled. This explains cases where the dust of the air, containing disease germs, produced violent epidemics among people drinking rain-water.

As regards the theory which attributes the negative electric charge of the earth to rainfall, it cannot be said to be sufficiently proved.

We must not grumble at the harmless hail-showers of March. Their little wet sprays which come in puffs, like from some gigantic censer worked on high by Jupiter Pluvius, are beneficial. The rain falling in Paris for the whole of that month, uniformly spread over the soil, would not be two inches deep. This is very little considering that in India nearly forty feet of rain are registered every year, and that as much as three feet can fall in a single day. It is much, of course, as compared with certain Peruvian deserts or the Sahara, where only perhaps an eighth of an inch falls per annum. Everything considered, Europe, from the point of view of rainfall, as well as other things, has the privilege of the happy medium, the measure of equilibrium.

Thus we must accept with indulgence those showers of March which in Old French were prettily called *guébelettes*. They have this charm. They sprinkle the green meadows with pearly drops. Even in the towns the octagonal roofs of open umbrellas have a certain oriental charm. And as an unknown poet wrote when skirts were still worn long :

> " *Et surtout j'aime dans les rues,*
> *Quand sur le macadam il pleut,*
> *Et que les jupes ingénues*
> *Se relèvent un petit peu.*"

Even the magistrates charged with keeping public order have sometimes blessed rain-showers. They have been known to quell riots. Thanks to this unexpected aid, the police have only been mobilised to contemplate "the remains of a rain-shower and an expiring ardour." Rain is a counter-revolutionary phenomenon.

And here comes Easter, which forces us, in despite of our firm intentions, to break the chronological order of our commentary. For if Easter sometimes falls in March, it falls more often in April, so that we have a break in the procession of our ideas, which we should have liked to follow the unrolling of the monthly ephemerids.

On the Thursday before Easter all the bells of the churches are silent, having, according to the quaint legend, gone to Rome. All we have then are the amethyst bells of the budding hyacinths which shed their perfume under the cones of the fir trees and the Roman arches of the oaks. But their great metallic sisters are back in their steeples by Saturday, and after the closing of their bronze mouths they welcome Easter on the Sunday.

In 1914, for instance, Easter fell on the 12th of April, but in 1913 it was the 23rd of March ; in 1916 it was the 23rd of April. Whence these differences ? The fault is that of the Council of Nicæa, which, in A.D. 325, decided that Easter Sunday should be the Sunday immediately following the first full moon after the 21st of March. The reason for this decision was that, according to the Scriptures, the resurrection of Christ took place after the Spring Equinox and a full moon. It followed that Easter could not fall before the 22nd of March, nor after the 25th of April. But it could fall on any of the intermediate 35 days. This mobility of Easter has already given rise to numerous difficulties. Several economic reasons have been advanced in favour of fixing the date of that festival, particularly as regards tourist traffic and the industries based on fashion. Several commercial congresses have passed resolutions in this sense. And the stay-at-home reformers who claim the privilege of regulating all human affairs have urged that since Christmas, the anniversary of the birth of Christ, is celebrated on a fixed date, it would be logical if the date of the resurrection did not occur at such a variable interval.

It is obvious that such a matter can only be settled in agreement with Rome, since nobody has yet succeeded in secularising Easter. Semi-official *pourparlers* had begun in 1914 on this subject. The late Cardinal Rampolla had written to Professor Foerster, the head of the Berlin Observatory, who had initiated this movement, that no doctrinal reason stood in the way of the projected reform, as the latter concerned practice and not dogma. That was a great step forward. Unfortunately, shortly before the war, several men of learning received from Rome the intimation that, after enquiries addressed to the clergy of various countries, the Holy See had decided in favour of the *status quo*.

One of the reasons which must have weighed with the Roman curia was that all the ardour of the logicians and the workers for uniformity had failed to secure the adhesion of all civilised countries to the Gregorian calendar. The Slavonic States, and particularly the great Russian Empire, had not yet adopted it, preferring to oppose logic rather than agree with the Pope. Thus the orthodox calendar is 13 days behind ours, and this gap will continue to grow by three days every four centuries. In 1914, the International Association of Academies met at St. Petersburg and discussed the matter, but no agreement seemed in sight, on account of political and religious reasons. There was nothing even to show that the ignorant mass of the moujiks would not make a revolution if an attempt were made to increase its age suddenly by thirteen days. More than one ex-beautiful woman would have found cause for complaint, and that seemed to be a serious stumbling-block for the reform. Besides, a sudden change of date would have entailed serious inconvenience to practical affairs in the Slavonic countries.

In order to avoid a change, a high Russian Tsarist official made the serio-comic proposal to put off the reform until the ever-increasing lag of the old calendar behind the new amounted to just one year. That would happen in 470 centuries, and would require a trifle of 47,000 years of patience. Thus the 12th of April of the year 48914 new style would be the 12th of April 48913 old style.

We shall see later, in the chapter devoted to the reform of the calendar, that since the war (an ill wind) things have changed their aspect, and that the day is in sight when all Christendom, and many of the non-Christian States, will employ none but the Gregorian calendar.

While we await this happy day, we must not take the difficulties of the calendar too tragically. Although Easter oscillates a little in the rigid form of the ephemerids, it remains the festival of all the resurrections, including that of spring crowned with tender primroses. Yet there are sophisticated people in search of novelty to whom this does not suffice, who want something new, not something renewed. Old

Kant was one of these, and in his declining days, when he saw the new April rejuvenate and awaken the chestnut trees in his garden, he exclaimed with annoyance: "It is only the old story." He was both right and wrong, like all those to whom the illusory pageant of events suggests any opinion whatever.

He certainly was right inasmuch as the universe is really rather uniform and homogeneous. In revealing to us that in the depths of the sky, among the farthest stars of the Milky Way, the same laws impose eternal standards on matter and energy, science has brought into the world a grandiose but somewhat monotonous uniformity. How much more quaint and unexpected it would be, how much richer in fancy and in possibilities, if the laws which govern things differed from one planet to another, or even from point to point on the same planet! Then everybody could, by a simple displacement, find a little world ideally adapted to his complexion. Unfortunately science teaches us that what is truth on this side of the Pyrenees is truth beyond them, though it may be sad for the wistful lovers of the Unreal.

And now June brings summer back to us, commencing always about the 20th of this month. In 1924 it was the 21st, at 16 hours, 59 minutes, 37 seconds of French official time, in other words, Greenwich time, to which we must add one hour to make summer time. In 1925 summer will commence on the same day but at 22 hours, 50 minutes and 13 seconds. At that precise instant the sun, having attained its greatest deviation to the north of the terrestrial equator, begins to descend slowly towards the south.

The ancient civilisations celebrated the solar culmination, the sign of summer, with magnificent and sanguinary festivals. At that time, men, like living heliotropes, raised suppliant faces towards the sun, which, in its sanctuary with the blue dome, was like a mystical and flaming monstrance. Christianity with its marvellous power of adaptation, made this celebration into the Feast of St. John. Now, as then, we magnify the solar splendour with symbolic bonfires. In olden times the savage worshippers of Baal and Moloch burned their infants. To-day the children merrily skip across the fires of St. John. This shows that we are a little more civilised—or that we have fewer children.

At this time our hemisphere receives the maximum heat from the sun, but this does not apply to the whole earth. The latter, as we have said, describes an elliptical orbit which varies our distance from the sun, and it is precisely in the first days of July that the sun is farthest from the earth, being then 95,000,000 miles away. In summer, the earth as a whole receives an amount of solar heat which is one-tenth less than in January, and the sun then has its smallest apparent diameter. In 1924, it was on the 3rd of July at 13 hours (1 p.m.) that the sun had its apogee.

While, in our latitudes, the sun sends most heat about the 22nd of June, how is it that the annual maximum of temperature only occurs some weeks later? Though the causes of this are rather complex, a rough idea can be given as follows:

If the soil radiated away the sun's heat as it received it, and did not absorb any, the maximum temperature near the ground would occur on the 22nd of June. If on the other hand the ground stored all the solar heat its temperature would increase indefinitely from day to day and from year to year. The reality lies between these two extremes. The ground only absorbs a fraction of the solar radiation, and as it heats up it loses by radiation into space a portion of its heat. It follows that the highest temperature will not coincide with the solstice nor follow long after it. It lags slightly behind it. The lag is found to be greater over the seas than over the continents. That is due to the fact that in order to heat up by a given number of degrees, water requires more heat than land, or, in the jargon of the physicists, "its capacity for heat is greater."

The same causes bring it about that the daily maximum of temperature occurs, not at noon, but towards 2 p.m.

If I am permitted to use a somewhat trite comparison, I should say that the sun is like a man of genius. It is only when he commences to decline, and not at the height of his course, that the effects of his radiation are most vividly felt.

Now comes the second fortnight in July with its very absurdly named "dog days," which produce so much inertia and prostration.

Of all the radiant energy which the sun projects into immeasurable space, the earth receives not even half of the millionth part. It is not much, yet in July the most particular persons will agree that it is enough.

We wait in vain for the blessed rain to temper the torrid heat, though if it were to come we should only grumble at it. The mercury remains steadily at the top of its scale, and seems in no hurry to descend from its pinnacle.

And everybody blames the dog! Now the dog has nothing to do with it, for the sufficient reason that he has not yet entered upon the scene.

And what are, strictly speaking, the dog days? They are the time of the year when Sirius, King of the starry realm, begins to be visible in the dawn just before daybreak. Sirius, the Dog Star, is the principal star in the Greater Dog (*Canis Major*). Hence the name of Dog Days.

Among the ancient Egyptians, the "heliacal rising" of Sirius, which began to be visible about the summer solstice, was a joyous and sacred event, since it announced the fructifying flood of the Nile. Among the Romans, on the contrary, the dog days had an evil reputation, and they were in the habit of sacrificing a red dog to expiate their sins. Rightly or wrongly, the odour of its blood was supposed to be agreeable to the nose of the legendary dog, of which Sirius was the blue and flaming eye.

Now this is what has happened: On account of the precession of the equinoxes, the heliacal rising of Sirius now takes place much later than it did in ancient times. In mid-July, Sirius is still drowned in the light of the east, and it is only in the second half of August that it can be seen with the naked eye, just before sunrise, posed like a marvellous pearl on the rosy fingers of the dawn. It is only then that the dog days really commence.

And yet, by a prejudice which has survived centuries—only errors have such tenacity—we continue to call the days following the middle of July the dog days. And I do not flatter myself with the hope that my explanation will destroy this error. There are, in the mind of the people, many noted opinions which may have been true and useful when

Rameses reigned in Egypt, but are no longer so in these days when King George V extends the British sceptre over the Nile.

So, after having carefully, for fear of error, examined their instruments with a magnifying glass, the meteorologists announce generally that it is very hot towards the end of July. And those absent-minded people whom this fact might have escaped are grateful for this official assurance.

One is surprised sometimes to find that the temperatures indicated in the same town are very different. In truth, the saying that "there has been such and such a maximum temperature to-day" has no meaning unless the conditions of observation are specified. In order to find the temperature of the air, one must above all not place the instruments in the sun, for the numbers so obtained have no relation to what we want to measure, but depend upon the material of the thermometers. By covering the bulb of one with lampblack, a temperature as high as 158° F. has been obtained. The same exposure would have yielded a much lower temperature had the bulb been whitened with chalk. None but readings taken in the shade are of any use, and even these are not strictly comparable from one station to another owing to various circumstances.

Yet if we consider that of all the shade temperatures registered at Paris Observatory for nearly 200 years none has surpassed the 40° C. (104° F.) observed, according to Arago, on the 26th of August, 1765, it is evident that summer in Paris is never excessively hot. Parisians would be much hotter if they gravitated round Sirius instead of round the sun, or if they inhabited certain regions of Southern Algeria, such as Touggourt, where 122° F. have been observed in the shade.

The genial anomalies of the seasons are just sufficient to renew perpetually those meteorological aphorisms which make up nine-tenths of human conversation. It would even be an interesting subject for an academic competition : "The influence of the Obliquity of the Ecliptic on tea-time conversation."

The next stage in our gradual progress through the year now takes us to the second equinox, which marks the commencement of autumn, and which, on the 21st, or the 22nd, or the 23rd of September, sounds the knell of passing summer. On that day the sun, like a copper ball suspended by an invisible annual pendulum, so few oscillations of which suffice to mark out our lives, passes once more exactly across the equator.

And here we see once more the barbarism of our so-called civilised society, their contempt and neglect of what should interest them keenly, but which their miserable ingratitude ignores and disdains.

Nothing is done among men to celebrate the spring, nor is anything done to mark the coming of the second equinox.

No ceremony distinguishes the coming of mellow autumn, the spring of the chrysanthemums. There is no pealing of bells, no flying of flags. But there is one consolation : No topical speech issues from the summit of a black coat to celebrate it in resounding and stereotyped phrases. Yet the autumn equinox should be for us the most solemn of anniversaries if we were reasonable animals, and if all the little events and the little "great men" whom we commemorate left us any time to celebrate the only things which matter. The year having been defined by astronomers as the time which elapses between two identical equinoxes, the end of the year should logically be the autumnal equinox. For of the two equinoxes it is the one in which northern vegetation completes its round.

Yet it is strange that none of the calendars ever used began the year at the equinox. For most people, next year commences on the 1st of January. For Mahomedans it is the 11th of December, for the Chinese the 18th of February—and there are more and worse. How can a thing as well defined as the year, more particularly the tropical year, which alone counts in civil life (though astronomers, as we have seen, know several others), how can it begin at such different moments under different latitudes? There are many reasons, and especially that if logic reigns anywhere in this world—and I do not guarantee that it does—it certainly does not do so in the calendar.

Yet after a careful search I do find one which commences the year at the autumnal equinox, or did commence it, for it no longer exists. I refer to the Republican Calendar. And since the autumnal equinox reminds us of the 1st Vendémiaire of the Revolution, may I be allowed to commemorate the commencement of the revolutionary year by gathering a bunch of tender memories for the short-lived calendar of the convention such as one does not deny to charming and rather absurd things which are long dead.

If the Gregorian reckoning appeared in 1793 fit for the waste-paper basket, it was perhaps not only due to the prevailing tendency to suppress all existing things on principle. Established by Julius Cæsar and revised by Gregory XIII the calendar had (and still has) the irremediable blemish of being doubly Roman. In this joint work of a famous tyrant and a pope, there was the collaboration which M. Homais, whose grandfather called himself Citizen Homais, called afterwards "the sword and the sprinkler." The Conventionist Romme was the most ruthless detractor of the Gregorian calendar. He never rested until he had, by his speeches and his flaming propaganda, got it condemned to death. Romme meant to destroy what Rome had made!

What took its place had several notable qualities after all. All the months had 30 days, with 5 or 6 supplementary days in the year. This was a revival of the Egyptian calendar, as was the "decade" substituted for the week. The days of the decade *primidi*, *duodi*, *tridi*, etc., had the advantage of always corresponding to the same day of the month; the beginnings of the seasons were always on the 1st of the month. All this made the calendar of the Convention one of the most logical and least conventional devices imaginable. But it had very serious defects, and especially the claim of being altogether logical, and it perished by those very logical defects. Yet what a picturesque charm there is in the names which the elegiac imagination of Fabre d'Eglantine bestowed upon the months! I do know that certain etymologists, after adjusting their spectacles, have discovered that these names are not all consistent with linguistic orthodoxy. But Floréal, Prairial, Germinal, Messidor, Brumaire and the others are still delightful to French ears. They are, however, too French. What could Frimaire or Nivose signify in hot parts of the globe where hoar-frost and snow are unknown? Or Vendémiaire in Norway, or even in some parts of France where vineyards do not exist? And in another hemisphere where the seasons are reversed it would have been necessary to shift the list of names by six months for fear of offending the natives.

As regards the names of saints, which were clearly counter-revolutionary, they were replaced by others derived from agriculture, at the risk of exciting the jealousies of commerce and industry. Thus, Monday, 23rd of September, Saint Linus, or Sunday, 29th of September, 1912, which was Saint Michael's day, would be in the Republican calendar Primidi Vendémiaire *Raisin* and Septidi Vendémiaire *Carotte, an* CXXI respectively. What would the grape signify to our Flemish peasants, or the carrot to regions (I believe there are such) where it is not grown.

The republican calendar perished for political reasons, true, but also from excess of its picturesque qualities. That which is picturesque and precise can only be local on a planet where there is so little uniformity. An almanac must have vague denominations in order to be universal. Now the names of saints are as universal as anything in this sense that, if their sanctity is uncontested, there is no reason why Saint Michael or Saint Linus should be called by different names in Perpignan, Brighton, or Zululand.

And then, what a crazy idea to call the supplementary days the "sans culottids"! Ridicule cannot have killed in 1793. It is true that in those days there were other and very expeditious ways of making people pass from life into the Beyond.

Yet there is one thing which places the Republican Calendar beyond competition. It was the only one which made the year start at its real beginning, the autumnal equinox. But a doubt occurs to me on further reflection: was it only a fortunate coincidence? The Republic was proclaimed on the 22nd of September, and the new year was thus begun. Must we suppose that the convention chose this date on purpose to make the proclamation? I doubt whether any historian will venture to maintain that, for the nation had at that time many other fish to fry, and many other tyrants to chastise.

The Republican Calendar is dead, and is better dead. Yet it is immortal, for Thermidor, Brumaire, and a few other resounding dates, full of sorrow and splendour, will echo for ever in the memories of men.

The almanacs which have survived have a single advantage over the almanac of the convention: they have no claim to coherence. They are wise. Is it not amazing to find that the ninth month of our year, which gives birth to autumn, is still called "September," on the pretext that it was the seventh month at the time when the Roman year began in March? If we wished to point all these incongruities, there would be no end. But our calendar has already survived many of its critics, and we shall not be the last, even though we live to a hundred.

But in spite of the various and often ridiculous names which the almanac has given to these days, it is always agreeable to abandon ourselves to the lustrous charm of the equinox, the morning of autumn. This season also has a curious privilege; while all through literature winter, spring, and summer have, each in its own way, evoked fairly uniform images and sentiments, autumn has appeared both sad and gay in turn. For some time men adhered to the ancient tradition which figured him (or her ?) as a buxom and rather wild Bacchante laughing under the grapes which covered and tickled her head, and listening to the gay music of the winepress and the trickling of the golden must. But the modern Bacchic poets have forgotten that image. They have substituted the *apéritif* for the liquid treasure of September, which, for its own good, they allow to grow old in the dark place where barrels are stored. The Greeks cannot have known the melancholy of the northern season's end, or they would not have left us that aggressive and rather vulgar type. The romanticists and their followers only saw the morbid charm and the agonising tenderness—another exaggeration.

Fortunately it is no longer necessary to be a young consumptive in order to be interested in the falling of the leaves. For every swallow it sends away, autumn leaves us a hundred lovely sparrows. And with its pretty russet patches, its tints which pass from clear amber to blood-red cornelian, the autumn forest is richer than the monotonous greenery of summer woods. September should be blessed, if only because it frees the bright copper of the foliage from the chlorophyllian verdigris which masked it.

For all these reasons the autumn equinox, which to-day is unobserved, may one day be a universal festival, when men will join in the celebration of the great natural phenomena which mark the rhythm of the earth. Then geolatry will be the State religion everywhere. But that is not yet. And I believe the word itself was non-existent a moment ago.

The most notable autumn event in the calendar is the Feast of Saint Martin.

The 11th of November is, indeed, devoted to the good Bishop of Tours, and for two or three days, if we believe the popular sayings, a sunny summer mildness softens the authority of autumn. But can we believe the people? There's the rub. Meteorologists tell us that if we take the average of a sufficiently large number of years, there is a distinct rise of temperature from the 11th to the 13th of November, but that is only true in the average, and our thermometric pundits lie low if we ask them what will happen this year or next year. "The exception proves the rule," and Montaigne's admirable "perhaps" is, we must confess, the Alpha and Omega of meteorological prophecy.

Without concerning ourselves with knowing much in advance whether a given year will be out of the average or within it—it could be a very ephemeral contingency, and the observatories will give us copious information after the event—we may ask what is the origin of the set of fine warm days which usually constitute St. Martin's summer. No better explanation has yet been found than the shooting stars; which in the last resort involve the comets.

The period from the 11th to the 13th of November is that in which the largest number of shooting stars is observed in the whole year. In those nights many of the cosmic rockets are seen to pierce the ebony of the nocturnal dome with their fiery tears. From time immemorial showers of shooting stars have been observed at that period, and for a long time November has been the greatest fireworker of the calendar. The old chronicles of the Middle Ages often mention that about St. Martin's day "terrible fiery lances" traversed the sky, or that it "rained blood over Paris." When this occurred in A.D. 561, shortly after the death of Clotaire, it was regarded as a sign of the interest which the heavens took in that event. Since then, of course, the meteors of November have appeared again many times, though Clotaire is dead long ago. But it may have been to commemorate him!

We know now that the shooting stars of the 11th or 13th of November, which are called the Leonids, because they seem to come from the constellation of the Lion, are small fragments of an ancient comet which formerly described an elongated ellipse round the sun, but has now broken up and sown its fragments all along the orbit, like an enemy on the march trailing a long line of hangers-on. Every year the earth encounters this long ribbon of small heavenly bodies about the 11th of November. A large number of them traverse the heights of our atmosphere with a speed of from 10 to 40 miles per second, and at a height which often exceeds 60 miles. They get heated up by their friction against the air so as to become incandescent. But the main condensation of the material of the former comet completes its orbit in 33 years, as the comet itself did formerly. It is therefore only every 33 years that the shower of Leonids is really beautiful. It was so in 1886 and in 1899, and will be so again in 1932. That there is some relation of cause and effect between the Leonids and St. Martin's summer seems almost proved. It is calculated that some 20,000,000 of them traverse the atmosphere on three November nights and days. As regards the mechanism of their action, there is as yet no agreement. Some attribute it to the heating of the air by the meteorites, others to an increased amount of solar heat reflected in our direction. *Se non è veno.*

When good St. Martin used his sword to bisect his mantle in order to cover the shoulders of a poor man—which alone was a novelty, since historically the sword has been more often used to cut other people's garments—he never thought that some day, in connection with his name, the figure-jugglers would write heavy volumes about the comets which, like men, lose their hair in old age.

The Indian Summer of St. Martin, though its reality may not be absolutely certain—and has not the reality of the external world itself been doubted? —is none the less charming in the images it calls up. It is a last spell of ardent youth which suddenly animates the declining year, when autumn has passed its russet brush over the landscape. It is the last wave, fragrant and harmoniously curved, of a sea which finally breaks on the beach. It is the last shudder, the dying sweetness of beautiful things for which there is no to-morrow. And then, from the core of December, there emerges the winter solstice and Christmas. Everybody knows that Christmas is the festival commemorating the birth of Jesus Christ. But the nativity of the divine Infant and the winter solstice fall so close together that we naturally connect them in our minds.

To tell the truth, the date of the birth of Christ is not known. The four Evangelists do not mention it. The festival was held long after the propagation of Christianity had begun, at dates varying with the country and the sect, sometimes in December, sometimes in January, or even in April. It was only in the fourth century that Pope Julius I fixed it definitely for the 25th of December.

On the other hand, the worship of the sun was very widely spread in the Orient, particularly in Egypt, in Syria, and even in Palestine. The winter solstice was lavishly celebrated there as the day when the reborn sun began to raise its pale but radiant head towards the north. From that day the days increased, as did the hopes in human hearts, and joy in the slumbering earth. The Infant Jesus, who visits us with the newly born sun, reminds us of the solar myths which, like those of Adonis, Horus, Dionysus, and Mithra, filled the old world with poetry. Yet we must not exaggerate this symbolism. The tendency to do so was very prevalent last century, when philosophy was in its infancy, so that a serio-comic scientist could prove, with all the rigour of the scientifico-philologico-nigological method, that Napoleon I had never existed, and that he was a solar myth. Let us beware of excess in that direction.

One thing, at any rate, is certain. According to the testimony of St. Leo, there were in his time many people in Rome who at Christmas confounded the birth of Jesus with the return of the sun. It cannot be doubted that such considerations led Julius I to fix the date of the birth at 25th December.

The missionaries who converted the ferocious Germans, the cannibal Celts, and the barbarous Slavs found that solar festival established, and gave it a Christian flavour. Knowing the tenacity of pagan customs, they were satisfied with changing the ideas rather than the forms, and this is certainly one of the greatest miracles wrought by the gentle teaching of the Redeemer.

But how will the computers, if Christmas is nothing but Christ's birthday, explain that its date is fixed, while the date of His death, which is two days before Easter, is movable? Easter falls on the 23rd of March in one year and may fall on the 12th of April another year. There is a great lack of system in these anniversaries.

As to the ingredients of the festival, they are local, and, I may add, meteorological. Father Christmas with his snowy beard, his hooded mantle, and his lucky hamper, is Mr. Winter, as unknown in Syria and Palestine as the Christmas pudding and stuffed turkey, without which an English Christmas is unthinkable, though not older than the discovery of America, the land of the quaint and toothsome bird. The holly and mistletoe, and the Christmas tree itself, are plants which remain green in winter and symbolise the life which is always latent in slumbering Nature.

The night watches in the churches, the crowds prepared by some hours of fasting for the austerities of prayer, as well as for the material indulgences to follow, celebrate in their own way the Birth originally witnessed by the simple ox and ass. Instead of their lowing and braying, we hear the deep chest notes of the leading tenor, for times have changed since Molière in his winding sheet was refused admission to Saint-Eustache because he had played in the theatre! Then in the restaurants, those lay cathedrals, the delights of the digestive tube succeed those of the soul. Let us not despise these rather vulgar merrymakings. Joy is always beautiful. Whether Christmas is the festival of the reborn sun or of Him who for so many years has been the sun of our souls, let us celebrate it in our hearts, for it is the day of Renewal.

A blessing on Christmas, on Noel, the natal day, which brings joy to children and indigestion to parents, which makes the family hearth burn brightly (where there is no central heating), which in some parts of the world makes slippers, placed by the chimney, as precious as Cinderella's slipper. We cherish a tender memory of the things we have adored, and we are reminded of the days before reality had killed our fond illusions.

Now here is one of the most singular of the paradoxes which are presented to us by the annual sequence of the days.

We have already said that the duration of the 24-hour day is conventionally fixed as the average of all the days of the year. This convention, to which we shall return later when dealing with the hour, was necessary because the real sun has a rather irregular apparent motion from east to west, which is not at all uniform. The variable speed which seems to convey the sun in its daily course from east to west is due to the fact that the distance between the earth and the sun varies in the course of the year, and to other causes as well.

We have therefore been obliged to define the *mean solar day* as the interval separating two successive meridian passages of a fictitious sun which, like the real sun, would cover the ecliptic in one year, and would coincide with it at the equinox, but would cover the distance at a uniform speed.

If, however, we consider the *true day*, that is, the time between two successive passages of the real sun across the meridian, what do we find? We observe that the durations of the real days are unequal, and the day is longest at the winter solstice! It is then 28 seconds longer than the mean solar day, while at the time of the equinoxes it is some 20 seconds shorter.

Thus, when examined closely, the 22nd of December, which is commonly considered the shortest day of the year, is really the longest.

This rather paradoxical contradiction is due to the fact that the word "day" in ordinary language designates two very different things, the time between sunrise and sunset on the one hand, and the time between two successive risings or settings, or rather between two successive culminations, on the other hand.

And science is said to be primarily "a well-constructed language."

After this rapid hour among the irregularities of the seasons and days, this voyage among the almanacs in which astronomy accepted the cheering companionship of a little fantasy, we must cast a brief look backwards.

What are the days, months, seasons, and years? Simple milestones placed by our pensive imaginations on the banks of the river of time which bears us onward, those banks which we can never reach to find an anchorage. Need we regret that we are not like that infinitely perfect Being imagined by Poincaré, of whom time is non-existent because Past, Present, and Future are equally present before him?

I believe not. I believe it makes for happiness not to be like him, for the possession of things is not worth the exquisite anguish of having lost them. Sketched in the magic mist of the Past, grimaces become smiles. Oblivion is sometimes precious and consoling.

The days are like water, which is most beautiful when it flows. And in an old palimpsest, illuminated in red and gold, there is a more poignant thing than the hard clear Gothic characters: It is to find under their ink the half-effaced verses of a gentle poet of Hellas.

CHAPTER III

THE REFORM OF THE CALENDAR

Cæsar, Gregory XIII, and the League of Nations—The day, month, and year incommensurable—Inconvenience of movable Feasts—The wanderings of Easter—A necessary generalisation of the Gregorian calendar—Other reforms needed—Necessity of intercalary days—Equal quarters or a year of thirteen months?—From Plato to Fresnel.

NEXT to the pleasure of killing time, nothing pleases men so much as to dissect it into well-grouped sections. Hence their interest in the calendar.

Much is expected of the League of Nations for the reform of the calendar, and with good reason.

I can hear the amateur diplomatists of the Commercial Café facetiously explaining that the League of Nations has many other fish to fry, and that economic, political, historical, and geographical questions are enough to absorb its attention to such an extent that no time will be left for trivial questions of the almanac.

To this I should respectfully reply that if the reform of the calendar is not a vital matter, that is an excellent reason for putting it at once at the head of the agenda. History and psychology agree in showing that the great problems, the problems of the highest importance, which affect all the interests and raise all the passions, are the most difficult of all to settle. Only the small questions can be tackled with any chance of a successful solution. A country or a man who only tackles the biggest things would lose time and fail to solve any, and this is as sure in science and in metaphysics as it is in politics. But let us return to the calendar, which is closely bound up with these considerations.

The best proof of its appreciable importance is that Cæsar himself, and afterwards one of the greatest popes, and after him the Convention, that other Cæsar, deigned to devote their intelligence to its improvement. And when the English passed from the Julian to the Gregorian calendar and the date suddenly jumped from one quarter to the next, there was a riot among the people. Evil tongues say that some great ladies of the aristocracy had a hand in this, because the jump in the date affected their coquetry. I could give a thousand other proofs. But I shall confine myself to pointing out the defects of the present-day calendar, hoping that they are of such slight importance that their correction will not hurt or harass anybody, nor put too many interests or customs on the defensive.

All the drawbacks of the almanac, all the complications and irregularities of the various calendars used, proposed, or discarded are due to the fact that there is no common measure of the day, the lunar month, and the year. To put it more drastically: (*a*) There is no whole round number of days between two consecutive returns of the same season; (*b*) there is no whole round number of days between two consecutive returns of the same phase of the moon; and (*c*) there is no whole round number of lunar months in the year. The tropical year, which is the principal unit imposed by nature on our subdivision of time, contains in fact, as already stated, a fractional number of days, amounting to 365·24219879.

The time which elapses between two full moons or two new moons, which is, of course, what determines the month, equals 29 days, 12 hours, 44 minutes, and 2·8 seconds, and is not contained a whole number of times in the year.

To speak only of the principal calendars still in use among so-called civilised peoples, it is sometimes the month and sometimes the year which preponderates, and different systems result. In the Jewish calendar, and in the Mahomedan calendar, the month is the important thing, and this is very natural, for in the East, where these systems originated, the seasons are but slightly marked, while the generally clear nights and the nomadic life endow the phases of the moon with importance. The Mahomedan calendar does not concern itself with the seasons. The year consists of 12 months of 29 or 30 days, and has sometimes 354 days, and sometimes 355. The beginning of the Mahomedan year, therefore, lags some ten days behind every year, and its New Year celebration passes through all our seasons. The Mahomedan year is shorter than ours, and when a Mussulman confesses to 36 years he is really 35. Hence our year 1924 corresponds to the year 1342 of the Hegira, although the " Flight " dates from 622 A.D., and only 1302 of our years have elapsed since. This is all very curious and little known, because few people think about it.

In the Jewish calendar, on the other hand, a jump is made every now and then, which makes the Jewish year, on the whole, equal to ours. A year of 13 months is occasionally introduced among the years of 12 lunar months.

The Coptic calendar need not be dealt with here, as it only interests a few sectarians. Otherwise the whole of Christendom employs one of two calendars in which the year is the essential thing and the month is secondary: the Julian calendar or the Gregorian calendar.

These two calendars only differ because in the former, used by the Orthodox Church, the three leap years are not suppressed in every four centuries, as Gregory XIII had ordained to bring the calendar into conformity with the true year. This results in a lagging of the Julian calendar, the year of which is too long. The lag now amounts to 13 days, and brings it about that the 1st of January 1925 of the

Orthodox corresponds to our 14th of January 1925. We must remark, however, that the days of the week are the same in both calendars, because when Gregory XIII instituted his reform he left the week untouched. Sunday among us is also Sunday in Eastern Europe.

It should be remembered that the institution of the Julian calendar by Cæsar at the suggestion of the astronomer Sosigenes, was based on the supposition that the year lasted exactly 365¼ days. In order to allow for this quarter, Cæsar substituted every four years a year containing 366 days.

Now it follows from the figure given above that the true duration of the year is a little less than 365¼ days, the difference being 11 minutes and some seconds. The Gregorian calendar was instituted to allow for this small difference. When it accumulates it makes a whole day in 128 years, or a little over 3 days in 400 years. The mean Julian year was therefore too long. In the Gregorian calendar, therefore, three leap years are suppressed in every four centuries, these suppressions taking place in the century years whose first two figures are not divided by four.

But the defects mentioned below, to which we must turn now, are common to the Julian and Gregorian calendars. Thus every reform which would remedy them would benefit all Christendom.

The first inconvenience of these calendars is one which is not an intrinsic one. It is that they are not universal. A number of inconveniences of international intercourse, difficulties of correspondence, and of commercial and financial exchange, result from this divergence, this multiplicity of calendars employed in the world. It is evident that the best way of persuading all States to adopt the same calendar would be to make the new calendar clearly superior to existing ones. This makes it desirable to examine the intrinsic faults of the Gregorian and Julian calendars in the first instance.

One of the most serious of these inconveniences is the variation of the date of Easter and the other movable feasts.

Recently the League of Nations, on the unanimous recommendation of a committee appointed to investigate this matter, on which the Holy See and the Orthodox and Anglican Churches were represented, passed the following resolution: "Concerning the fixation of Easter and other more general questions, from a strictly dogmatic point of view the reform of the Gregorian calendars does not encounter any difficulties which may be considered insurmountable."

This resolution, the stilted language of which is greatly superior to its grammatical elegance, signifies, if I understand it rightly, that the so-called competent authorities would take a favourable view of the fixing of Eastertide.

This problem, a necessary condition of every reform of the calendar, affects some very venerable ecclesiastical prerogatives. Hence the adhesion of the religious authorities to the above resolution is very important.

According to the rules closely followed since the Nicene Council, Easter takes place every year on the first Sunday following the first full moon after the spring equinox.

Since successive full moons generally fall on different days of the month, and these days differ for the same month from year to year, it follows that the annual date of Easter must vary considerably. Thus, in 1923, Easter fell on the 1st of April. In 1924 it fell on the 20th of April, three weeks later. This divergence can be even greater. In fact, according to the "computation," or the rule which enables us to calculate these dates in advance, Easter may fall anywhere between the 22nd of March and the 25th of April, a range of 35 days. The variation and mobility of Easter imposes grave and very numerous inconveniences on business, travel, tourist traffic, teaching, and agriculture. It has been shown that in certain countries trade loses millions when Easter falls in March.

These inconveniences are aggravated by the fact that the mobility of Easter involves that of many other festivals, notably that of Ash Wednesday, which, according to the computation, takes place 46 days before Easter, Ascension Day, which is 39 days later, and Whitsunday, which is 49 days after Easter.

If all the feasts were movable and at constant distances from each other, this system, however inconvenient, would at least be consistent. But that is not the case, and Christmas, for instance, falls on a fixed date which has no relation to the moon.

Thus the interval between Christmas and Easter, which should surely be constant, can vary by 35 days from one year to another. How can we admit that between the anniversaries of two important events in the life of Christ there should be such different numbers of days?

But this is not all. We shall show by a definite example that there is something artificial in these matters, even from the astronomical point of view. We have already mentioned that in 1924 Easter fell on the 20th of April. Now in 1924, the vernal equinox took place on the 20th of March at 21 hours, 20 minutes, 14 seconds. The first full moon after that equinox occurred on the following day, the 21st of March. Thus, according to the rules of the Nicene Council, Easter should have been celebrated on the following Sunday, the 23rd of March. But actually it was celebrated about a month later, owing to the fact that the vernal equinox has been fixed once for all for the 21st of March, which is not always astronomically true. The "moon" used in the computation is a theoretical moon, a fictitious and ideal moon, whose phases are retarded with respect to the real moon.

We must congratulate ourselves that the authorised representatives of the governments and religious organisations have declared that there is nothing in the way of ending this archaic complication, this chronological anarchy. We must now wait and see how much time it will require for this half-hearted resolution to become an accomplished fact.

Other defects of the present calendar are that the divisions of the year (months, quarters, half-years) are of unequal length, which causes continual inconvenience and uncertainty, loss of time and money, errors and injustices in the calculation of salaries, interest, insurance and pensions, rents and annuities, and current accounts. The first half-year contains 2 or 3 days less than the second. Some months have 3 days more than others. The number of days in the quarters is 90, 91, and 92 respectively. One fact suffices to show why from the simple banking point of view a chronological reform is indispensable: In most European countries the inequality of the months has led financial establishments to base calculations of current accounts and deposit accounts on a year of 12 months of 30 days each, a total of 360 days, while salaries are calculated on the actual number of days in the year. The fact that the months, quarters, and half-years do not contain an exact number of weeks produces a number of difficulties in all branches of business and accountancy, which are well known to all commercial people.

Furthermore, the date of the month does not fall on the same week-day in successive years. Periodical public and private events, anniversaries, maturities, fairs and markets, and meetings do not fall on the same week-day for a given day, and vice versa. The 1st, 15th, and 30th of a month is often a Sunday, to the great inconvenience of business men. The fixed feasts are often inconvenient, falling on Sunday or in the middle of the week. These drawbacks have led men, and particularly business men, to study the indispensable reform of these badly devised calendars, which cost immense sums and cause a thousand petty annoyances in the world.

Even before the war, international congresses assembled to popularise and study the question of reform. The most important of these took place at Liége on the eve of war. It passed the following resolutions :

(1) The International Congress for the reform of the calendar, assembled at Liége on May 27, 28, and

29, 1914, considering the multiplicity of calendars in use at present, and the necessities of modern life, recommends the civil and religious authorities to adopt a new *universal* calendar.

(2) The Congress recommends that the new calendar be a *perpetual* one, with agreement between days of the month and days of the week.

(3) Having considered the information and documents laid before it, the Congress sees no paramount obstacle, from the religious point of view, to placing one day out of date in ordinary years and two days in leap years.

(4) The Congress recommends that the year consist of 364 dated days, forming 52 whole weeks, plus the supplementary day in ordinary years and 2 supplementary days in leap years.

(5) The Congress recommends that the division of the year into 12 months be preserved.

(6) The Congress recommends that Easter be fixed for one of the first Sundays in April.

Obviously, the primordial drawback of the present calendars is that there are several of them. In Europe alone, the nations have three different chronological systems. The resulting inconveniences are similar to those which existed when every town had its local time and the units of measurement varied from one province to the next.

The time has been fixed so that at a given physical moment or "epoch" as it is technically called by astronomers, all clocks in the same country indicate the same time, always supposing that they are well regulated.

The important thing was, not that every town should keep a perfect time, but that all should keep the same time. The best proof that the perfection and scientific provision of the official time is of only secondary importance in a domain where so much is conventional, is that the official time has recently been changed on a number of occasions without much inconvenience. The chief point was that the time should be uniform.

The same applies to the calendar, which is indeed nothing but a sort of classification or language. It is desirable that everybody should speak the same language, imperfect though it be.

This was forgotten by certain persons who formerly, and especially in Russia, opposed the unification of the calendars on the ground that the Julian calendar is, after all, not much worse than the Gregorian, and that the Slavs would not adopt the latter unless all its defects were remedied. That is the sort of ultra-revolutionary Utopism which, claiming to aim at nothing but ideal perfection, never obtains anything. "All or nothing" is a very bad principle even in matters of chronology. For as in all human affairs one can never have everything, we must resign ourselves to putting up with something less. It were better to have one calendar of average merit than two good calendars, not to speak of two mediocre calendars, just as in war a single chief is always superior to several, even though they be excellent ones.

I therefore consider that the League of Nations was right to enumerate, among the international arrangements it is preparing, the unification of all the calendars employed by the nations, which unification shall be realised by the adoption of the Gregorian calendar. This for many reasons, both theoretical and practical, as we shall see.

Certain defects of the Gregorian reform have been noticed for a long time past. Here is one of them. The mean duration of the real year is 11 minutes and 15 seconds shorter than the Julian year of 365 days, 6 hours. That difference of 11·25 minutes attains the value of a day in exactly 128 years, so that the Julian calendar loses a day after every 128 years. In suppressing three days in every four centuries, the Gregorian calendar therefore suppresses a day in every 133 years instead of 128. The small Gregorian error is not very considerable, since it only amounts to 3 hours every 400 years, or one day in eight times 400 years.

Yet it had to be pointed out, for one must never tamper with scientific accuracy. To rectify this slight error and prevent its effects from accumulating, some astronomer has put forward the following rule, which would neatly rectify the Gregorian calendar and could well be adopted by the League of Nations: "The years divisible by 4 will be leap years, unless they are divisible by 128." Let us take, for instance, the year 1920. It is divisible by 128, with a quotient 15. This means that since the Christian era the Julian calendar has lost 15 days. But the difference between the Julian and Gregorian calendars is only 13 days, and that shows another defect of the Gregorian reform. When Pope Gregory XIII proclaimed his reform in 1582 it was only dated back to the Council of Nicæa (A.D. 325) whereas it would have been more consistent to date it back to the beginning of the Christian era. The error accumulated by the Julian calendar in the course of those 325 years exists also in the Gregorian calendar, and amounts to 2 days. Logically, a small correction should be made, which would bring back the vernal equinox to the date on which it fell at the beginning of the Christian era.

This is all very well, but if we want to succeed we must for the present leave these scientific refinements on one side. We must first demand the unification of the calendars by the generalised adoption of the Gregorian calendar which the League of Nations could impose.

In spite of its minor defects, the Gregorian calendar is greatly superior to the Julian, which is a much slighter approximation to reality. But apart from scientific reasons, there are imperious practical reasons for the general adoption of the former.

The first of these is that the Gregorian calendar is at present used by a much larger number of people and nations than the Julian. The second is that the centre of gravity of civilisation is incontestably located among the nations using the Gregorian calendar.

Finally and chiefly it is the course of events itself which, as we shall see, irresistibly impels the dissident nations towards the adoption of the Gregorian calendar, and of that alone.

China and Japan have recently adopted the Gregorian calendar officially, and Bulgaria has done the same since the outbreak of the war, in 1915, to be precise, on the occasion of the pompous visit of William II to Sofia. They had a curious reason for doing so. Since 1914, the Bulgars have blazoned it forth that they are not Slavs, hoping thus to explain their treasons against their liberators, the Russians, who since then . . . It was in order to break a link with Russia that after the visit of the War Lord following the crushing of Serbia the Bulgars solemnly and finally adopted the Gregorian calendar. It is an ill wind . . .

Thus the subjects of Ferdinand thought to give a positive proof of their intellectual rupture with their enemies. They forgot that they thus attached themselves not only to Germany, but to France, England, Italy, and the United States, all the great nations which use the Gregorian chronology.

What is interesting about it is that the reform was accomplished in Bulgaria in the simplest manner, without any disturbance. No riot, not even a protest marked this official ageing of a people by 13 days which fell upon it suddenly.

What was done without a shock in Bulgaria in war time seems, according to the latest information, about to take place in other Eastern countries, particularly in Serbia. The Peace of Corfu of the 7th–20th of July 1917, which founded the " Kingdom of the Serbs, Croats, and Slovenes " (the Serbs are Orthodox, and the Croats and Slovenes Catholics), provided in Article 8 that the calendar should be unified as soon as possible by the adoption of the Gregorian calendar. This has recently been done.

Rumania, Greece, and Turkey have done the same or are on the point of doing so.

Even the Bastille of the Julian calendar, its most powerful bastion, has entered upon the same path. One learns that for some time already the Bolshevik Government has officially adopted the Gregorian calendar, which proves that there is a reverse to every medal.

People have understood at last that religion has nothing to do with these questions of the almanac, more especially since China and Japan, who are not Catholic in any sense, have officially adopted the Gregorian calendar.

The objections raised by certain Slavonic personalities that there would be resistance, and justifiable resistance, on the part of the Orthodox clergy, do not appear to be well founded, as we have seen.

And besides, it is a fact little known among us, that among the Orthodox who use the Julian calendar, the Church does not use the same method of measuring time as does the Julian calendar adopted by Orthodox governments. The orthodox religious year begins in September, and not on the 1st of January, the official date. The years are not counted from the birth of Christ, so that the year A.D. 1919 is the year 7427 of the Orthodox Church.

Even the numerals used by that Church are neither Arabic numerals nor the Latin numerals we know. They are numerals derived from Old Slavonic letters. And thus, while the public authorities adopted the Julian calendar, the Orthodox Church remained faithful to its particular chronological rules.

Religion and the calendar can therefore be, as mathematicians would say, "independent variables."

Hence the official adoption of the Gregorian chronology by the Turks and the Orthodox can have no inconvenience.

To sum up, the general acceptance of the Gregorian calendar may and must be placed among the terms imposed upon the world by the League of Nations.

To subordinate this easy reform to the reconstruction of the whole mechanism of the calendar, of which I am about to speak, would be putting the cart before the horse, and running the risk of achieving nothing : *Qui trop embrasse, mal étreint.*

Having regulated this first point of practical importance, the League of Nations, discouraged, perhaps, in its laudable attempts to found an earthly Paradise, will perhaps tackle chronological reform more seriously. Here also it can be very useful, for many things are, unfortunately, to be corrected in the Gregorian calendar, which, at this point, will have become the only calendar of civilised peoples.

There are, however, some matters under dispute, as we shall see, and these disputes must first be settled by a competent authority such as the Academy of Sciences or some other body which will examine them. The surest means of obtaining a result with the League of Nations is to present to it something which is technically complete.

Since the Gregorian reform only one project of a reformed calendar has had a practical result, however ephemeral. It was the French Republican calendar.

The glance we have already cast on its qualities, and particularly its defects, will allow us to form a saner judgment of the reefs which must now be avoided in chronological systems if they are not to be shipwrecked.

The reformed calendars now offered must take care to preserve as far as possible those names to which mankind has got accustomed. And they must not insist on absolute consistency. Names are of the greatest importance.

Let us now pass the principal systems in review. I cannot describe them all, but only the categories in which they find a place. Besides, as it is not my business to discover and indicate the priorities of the various authors, I shall only mention some of them incidentally, without classification.

Most of these systems have been put forward, or at least particularised, in the course of an interesting competition recently organised by the Astronomical Society of France. The prize was awarded to M. Armelin, who proposed that the year consist of 4 equal quarters of 91 days each (two months of 30 days and one of 31 days). This makes 364 days. To these, either one day or two supplementary days are added, accordingly as the year is an ordinary year or a leap year. These supplementary days are not dated. Thus, each quarter has 13 whole weeks, and in all the quarters the same dates always correspond to the same days of a given week in the quarter.

Many authors have put forward analogous projects, which are really variants of the above. They differ either in the manner in which the 30-day months follow the 31-day months—several combinations are possible—or in the day of the week falling on the first day of each quarter; or again by the place given to the supplementary day or days, which may be separate or consecutive, and placed at the end of one or other of the quarters. I need not enter on the details of the various combinations.

It is clear, also, that each of these points has its own importance, and that it is not a matter of indifference whether or not the first day of each quarter is a Monday; whether the 15th or 30th is a Sunday, whether the 31-day month is the first, second, or third month of the quarter; or whether the supplementary days, which are intended to be festivals, are in the middle or at the end of the year, and follow a Sunday or a week-day.

But all these discussions would lead us too far. These matters are, after all, of secondary importance, and it will be easy to examine them and come to an agreement.

In this system, or systems, the present inequality of quarters and half-years is suppressed, there is a whole number—and the same number—of weeks in each quarter, and the same week-day always falls on corresponding days in each quarter, that is, on days three months apart. Most of the accustomed characteristics of the present calendar are preserved, while many drawbacks are remedied.

On the other hand, an American astronomer, Mr. Searle, has suggested that the years thus constituted should always have exactly 52 weeks, without a supplementary day, the latter being introduced every seventh year as a 53rd week. The Gregorian cycle of 400 years contains 20,871 weeks, which, with leap years, give 497 supplementary days, or 71 weeks, which could very simply be distributed periodically.

Then there is another group of reformed calendars. The best known of these is the Delaporte calendar. In this system, the year also consists of 364 dated days, plus one or two undated ones. But whereas in the previous system the quarter was the basis, it is now the week. The year consists of 13 months of 28 days each, making 364 days, and each month consists of exactly four weeks of seven days each. In this extremely logical and simple combination, the same day of the month always falls on the same day of the week, and the months have identical lengths. It is obvious that this calendar also comprises numerous variants according to the day which is to be the first of the month and the position of the supplementary days. The system is still more rigorous than the last one, but it also, by a natural consequence, contravenes old-established habits. Would the public admit a year of 13 months? It is not only a question of the superstition attached to the number 13, but also of the inconvenience and disorganisation to commercial habits resulting from the suppression of convenient subdivisions like the quarter and half-year.

That seems to have been the view of the members of the Liége Congress, for the reformation of the calendar since among the resolutions passed there is the following: "That the division of the year into 12 months be preserved."

Indeed, in reading through the resolutions of that interesting Liége Congress, we see that its tendency is towards the adoption of a system more or less analogous to the Armelin calendar. This I point out, without taking sides in the matter. *Adhuc sub judice lis est.*

Let us not seek an exaggerated scientific rigour in the reform of the calendar. That reform is demanded by practical considerations such as those which appealed to the Chambers of Commerce. The reform should be tackled practically. We must begin at the beginning, taking the easiest step first, which is the unification of the calendars in the Gregorian mould. *Chi va piano va sano.*

If we may be allowed to look at the matter theoretically, we see that all the difficulties, all the imperfections of the calendars proceed from the fact that the month and the week are not commensurable in the frame of the year. In other words, the synodic revolutions of the moon round the earth and the earth round the sun have no common measure.

One of the most singular errors of Plato, that divine dreamer, was to believe that natural things have only simple and perfect relations to each other. Thus, he sought to prove that there are only five perfect worlds because in geometry there are only five regular solid bodies.

Unfortunately, the truth is far otherwise. The real and profound harmonies of the world are not subject to the paltry limits of our logic. As Fresnel said: "Nature does not worry about analytical difficulties."

In any case, the fate of this question will enable us to judge the League of Nations.

Some persons believe the League is the chrysalis whence a better future will emerge on the luminous wings of Justice and Liberty. Others hold it is but the last and fugitive reflection of the illusory clouds of the Past. But belief is not knowledge. The reform of the calendar will help us in choosing between the two points of view.

CHAPTER IV

THE STARS AND THE DAUGHTERS OF THE SUN

The hour through the centuries—The starry vault as the master clock—Sidereal Time and Solar Time—The true day and the mean day—A fictitious sun as coadjutor of the real sun, which is too capricious—Local time and the hour sectors—A scientific Waterloo—The French Administration imitates Charles V, but lags behind Rudolph II.

THE day, the month, the season, and the year are natural divisions of time, imposed in some way by the phenomena themselves, by the daily course and annual rhythm of the sun, and by the periodically changing phases of the moon.

The hour is a different matter altogether. Nothing in the nature of things as presented to us obliges us to divide the day into 24 parts. The hour is, therefore, a perfectly arbitrary unit of time, just as the metre is an artificial unit of length which nothing suggests to the exclusion of any other.

This is so true that Homer and Hesiod only distinguish two parts of the day, viz. morning and evening. According to the Zend-Avesta the ancient Persians only distinguished five periods: Dawn, from midnight to sunrise; the Time of Sacrifice, from sunrise to about noon; the Time of Full Light, from noon till sunset; the Rising of the Stars, from sunset until the stars appeared; and the Time of Prayer, from starshine to midnight. Long afterwards, at the time of Varro, the Romans only distinguished seven divisions.

According to M. Bigourdan it was the Acadians of ancient Chaldæa who were the first to divide both day and night into 12 equal parts. This division was subsequently adopted by the Greeks and Romans, and then by all civilised nations.

But since the length of day and night is constantly changing throughout the year, and also according to latitude, the one gaining what the other loses, the result was that the 12 parts of the day were sometimes longer and at other times shorter than the 12 parts of the night. These parts were called temporary hours. In our climates, the temporary hours of the day are twice as long in June as they are in December. The reverse applies to the temporary hours of the night.

The hours were not equal except perhaps at the equinox. Many centuries elapsed before equal hours were adopted. These were called "equinoctial hours." Even in the fifteenth century people used to alter the pendulums of clocks every evening to make them divide the night into 12 equal parts. In the morning a different adjustment had to be made in order to subdivide the day equally.

The almanacs of Regiomontanus, at the beginning of the Renaissance, still announced astronomical events in terms of temporary hours.

It was the clocks which, on account of their all too regular movement, brought about the substitution of equal equinoctial hours for unequal temporary hours.

It was a similar process which, in the ultimate analysis, brought about the substitution of a fictitious but regular sun for the real sun for purposes of measuring time, as we shall see. The real sun was found to be too irregular.

Let us imagine a perfectly regulated clock, with all its parts perfectly constructed and free from every cause of variation, especially changes of temperature and pressure. By means of such a clock let us in a given plan observe the time elapsing between two successive passages of the centre of the sun's disc across the meridian, that is, its culminations at midday. We shall find that the time elapsing between two successive passages, that is, two successive true noons, varies through the year, and that it is 48 seconds[1] longer at the winter solstice than it is at the equinox. In order that a good clock should exactly follow the course of the sun it would, therefore, have to be retarded in winter and summer, and advanced at the equinox, which would be very troublesome.

[1] The second is defined as the 86,400th part of the mean solar day.

In reality, the clocks were for many centuries, and until recent years, insufficiently exact to indicate such small irregularities in the motion of the sun. If, in spite of this, such irregularities have been put in evidence, it is by a process analogous in principle, that is, by the observation of a clock which is much more perfect than the best man-made clocks, viz. the starry vault.

Whatever we may think of the true and absolute rotation of the earth with regard to a fixed point, which is not here in question,[1] there is a fact upon which all the world has agreed from the remotest antiquity: The celestial sphere on which the constellations are fixed like golden nails turns with respect to the earth, or in other words, the earth turns with respect to the celestial sphere, which, for our purposes, comes to the same thing.

We also know that the stars are at enormous distances away from us, distances which light, for all its speed of 183,000 miles per second, can only traverse in several years in the case of the nearest stars, or several centuries for the other stars.

Consequently, however rapid may be the proper motions of the stars—on the average they do not exceed a few miles per second—they are absolutely insensible and unobservable within 24 hours. Thus, while the earth makes, or appears to make, a com-

[1] See *The Kingdom of the Heavens*, Chapter VI.

plete rotation on its axis, the stars have not sensibly moved with respect to it.

The case of the sun is different. It is nearer to us, and its distance from the earth is 200,000 times less than that of the nearest star. Also, we know long ago that the distance between the sun and the earth varies. Hence *a priori* the observations of the sun, and of its return over a particular place, cannot furnish an exact measure of the earth's rotation.

But in the case of the stars the time between two successive passages across the meridian of a particular place, between two successive daily or nightly culminations, furnishes an exact measure of the earth's rotation.

If, therefore, instead of using the sun, we compare by means of a perfect clock the successive intervals elapsing between the passages of a given star across a given meridian, we find, contrary to our experience in the case of the sun, that these intervals are always rigorously equal from year's end to year's end, no matter what star be observed.

This duration, this interval which separates two successive meridian passages of the same star, has been called a *sidereal day*. The sidereal day is shorter than the solar day since the sun, receding among the constellations and entering the same constellation after a year's interval, makes 365 apparent revolutions of the earth while the constellations make 366 apparent revolutions.

The sidereal day is, therefore, about 4 minutes shorter than the mean solar day. It is subdivided into 24 sidereal hours of 60 sidereal minutes each, and these again into 60 sidereal seconds each. All these units are nearly 1-365th shorter than the corresponding units of the mean solar day.

It is sidereal time, therefore, which serves to time our clocks, even when the latter show solar time. We see, in fact, that the master clock which we use for subdividing time is really the terrestrial globe turning on its axis with respect to the distant stars. The earth's sidereal rotation is the standard, the real base from which we start to measure time.

The only hypothesis which we make in this measurement is that the earth's rotation is uniform, regular, and always equal. This hypothesis is not only probable but is largely verified by science, as far as any hypothesis can be verified.[1] Yet we shall see

[1] The fact that perfectly regulated clocks shielded from all known causes of variation (changes of temperature, pressure, etc.) always agree with the earth's rotation proves, as well as anything can be proved, that the earth's rotation is uniform and regular. If it were irregular, we should have to assume that perfectly regulated clocks undergo the same irregularities at the same time, which would be highly unlikely. We can only think that M. Poincaré was joking when he said we could not assert that one clock went well and another badly, but could only say that it was more convenient to time ourselves by the former.

that recent ultra-precise astronomical observations have shown that it is not absolutely exact, and that the duration of the earth's rotation varies very slightly, but so slightly that it does not affect the regulation of our clocks and the chronological sequence of our brief destiny.

Let us now compare the duration of the real day, that is, the interval between two culminating passages of the sun over a given spot, with the regular rotation of the starry vault, i.e. the rotation of the earth. We shall make that comparison by means of a sidereal pendulum regulated by the successive culminations of a star.

Since there is no reason to choose one star rather than another, it has been agreed to fix the origin of sidereal time at the meridian passage of that point on the sphere of stars which we have called the vernal equinoctial point.[1] It is situated on the celestial equator, and coincides with the centre of the sun at the spring equinox.

At the instant when that point passes across the meridian of a place, the sidereal clock at that place should point to 0 hours, 0 minutes, and 0 seconds. It follows that at a given place a clock regulated by the sun[2] and another clock marking sidereal time will

[1] Or the "First Point of Aries."—*Tr.*

[2] The astronomical solar day commences at noon.—*Tr.*

show the same time at the spring equinox. Every day after that, the sidereal clock gains nearly four minutes as compared with the solar clock, since the sun passes the meridian at every place with an increasing lag, which grows nearly 4 minutes every day as compared with the vernal equinoctial point. At the end of a month, the sidereal clock is two hours ahead; after six months, it is 12 hours ahead; and both clocks are once more in agreement at the end of a year.

If the daily lag in the meridian passage of the sun as compared with the stars were always the same quantity, the true solar day would be longer than the sidereal day, but it would always have the same length, and clocks could be regulated by it. This is unfortunately not the case, for the reasons we have stated. The real solar day, as compared with the sidereal day, has a duration which varies in the course of the year.

All this has some strange consequences. A good clock must show solar time. But if it followed the sun, it would require constant adjusting, and would have to be made faster or slower according to the seasons. That would be very troublesome. In order to meet this difficulty, a fictitious sun has been invented, called the "mean sun," which, like the real sun, makes a complete turn of the ecliptic in a year, but moves among the constellations at a constant speed throughout the year. The day marked out by this fictitious sun is the "mean solar day." The "mean time" which it measures is what has been employed officially since the nineteenth century. It is the time shown by the external clocks of the great Observatories and by other public and private clocks, while they are going.

In the old days, many Parisians who had bought a good watch compared it with the gun of the Palais-Royal, which, regulated by the sun itself, boomed at the real noon. Finding that their watches disagreed with the gun, they complained to the watchmakers, and were astonished when the latter told them that it was the fault of the sun. Many were dissatisfied with this explanation, which to some seemed impious. If I am not mistaken, the Palais-Royal gun has been sent to the Invalides, and that was right. After all, it is perhaps because he regulated them by the sun that Charles V found it more difficult to rule clocks than to rule men, in which he was probably wrong.

There is another curious consequence also. The times of sunrise and sunset given by the calendars refer, of course, to the real sun. It follows that in the spring the mornings are shorter than the afternoons, while the reverse is the case in autumn, and the difference may amount to half an hour. Is that why the poets praise a spring morning and an autumn evening?

"Regular as the sun" is an expression which we ought to banish from our conversation if we wish to be precise.

The differences between the course of the true sun and that of the mean sun are more considerable than is generally imagined. At Paris, for instance, a clock indicating mean time for the Paris meridian, that is, regulated by the mean sun for that district, rarely marks noon when it is true noon and the sun is culminating in the sky. In fact, it does so only four times per annum, viz. about 15th April, 15th June, 21st August, and 24th December.

The rest of the year, mean noon as shown by the clock is sometimes in front of, and sometimes behind, true noon. Its greatest advance is about 14½ minutes, and takes place about the 12th of February. Its greatest retardation is about 16½ minutes, which happens about the 3rd of November. Thus we see what errors might be committed by the people who regulated their watches by true noon given or boomed by the gun of the Palais-Royal.

All we have said applies to the clock regulated at Paris by mean time, which gave the official time to France to from 1891 to 1911. But since we have adopted Greenwich time the official clocks in Paris are 9 minutes, 21 seconds behind the mean time of the Paris Observatory.

It follows that in Paris the difference between the official noon and true noon on the 3rd of November is 16½ minutes *plus* 9 minutes, 21 seconds, a total of nearly 25 minutes. This difference is even greater in places west of the meridian of Paris, and attains 47 minutes at Strasbourg. This fact has contributed some scientific justification to the much-debated adoption of "summer-time."

If the clocks marked the true hour by the sun at every place, they could not show the same hour simultaneously in different towns, or even in different parts of the city. But if the clocks marked correct local mean time, the differences would remain the same. These differences are more serious than one would think. In the neighbourhood of London they amount to about 6 seconds for each mile of travel either towards the east or towards the west.

In Paris, local mean noon occurs 37 seconds earlier at the bridge of Charenton than it does at the Point du Jour.

Every time you take a cab ride or go for a walk you will, unless you confine your movements to the north and south direction, have to advance or retard your watch if it is to show true solar time or mean time for the place you are in. That would be theoretically ideal. But neither for watches nor for individuals is the ideal compatible with hard realities —in spite of the planners of future cities—and something else had to be contrived. In the first place, it was decided that all watches and clocks should show the same time in any given town.

In the case of Paris, this grave decision was taken in 1816. But, fearing a riot among the people of Paris, the Prefect, M. de Chabool, obtained a report from the Bureau des Longitudes before substituting mean time for apparent solar time. From that time civil time ceased to be in the domain of pure science. It could not be used for astronomical purposes, but became something conventional and grew more and more into a scientific heresy, as we shall see.

For many years every town had its local time. This was not very objectionable at the time of the stage-coach, when the good people, definitely enclosed in the little circle of their city, did not travel much. But railways and telegraphy brought about the substitution of a single time for all France, and this was decided by law in 1891. Local time for the whole country was then the mean time of the Paris meridian.

From that arrangement to the fixation of the same hour for the whole world was but a step. Systematic souls enamoured of unity took that step easily. But there is many a slip between the cup of theory and the lip of realisation. Very strange consequences might have ensued, for when the sun is high in the heavens in some countries it is black night on the other side of the planet. If universal time had been adopted according to this American proposal, we might have expected news items like this: "Yesterday at 9 p.m. at sunrise there occurred in Nouméa," etc. This would have disconcerted our habits of thought, though it might have had the advantage of teaching geography. Other people might have had a difficulty about opening their sunshades at "midnight," or saying "it is midday" at 2 in the afternoon.

An intermediate solution had therefore to be found, in the shape of "hour sectors." Since the sun apparently makes the circuit of the earth in 24 hours, and the circuit, like all circles, has 360°, it has been agreed to divide up the earth into 24 sectors of 15° each, cutting it from pole to pole like sections of an orange.

When de Musset compared our globe to a big pumpkin without hair or beard he can hardly have foreseen that some day the organisation of time-keeping would render that comparison so appropriate. In each of the sectors or zones which go from pole to pole it is agreed that the legal hour shall be everywhere the same and shall be equal to the hour prevailing in the middle of the sector. Thus, in all sectors the official time-pieces must show the same minute and second throughout the world. Only the hours differ, and in any given sector the time is one hour ahead of the next westerly sector and one hour behind the nearest easterly sector. The initial sector which governs all the others is the sector which is bisected by the Greenwich meridian. Gradually the different countries have adopted this meridian in large numbers, especially since, in 1911, the French Government acceded to it after having hung back a long time, and with some reason.

The drafting of laws has little to do with Astronomy—I am referring to human laws, which must not be confounded with natural laws. Yet French astronomers were somewhat dismayed when the legal time of France and Algeria, which was that of the Paris Observatory, was suddenly put back 9 minutes and 21 seconds.

Certain persons, whose scruples were quite praiseworthy, looked upon this measure as an abdication. They pointed out that if it had been adopted at the time when the old astronomer Janssen, in the name of France, refused to countenance it at the Washington Congress, it would have been extensively regarded as a sort of scientific Waterloo. The same people also pointed out that the adoption of this law would eventually, for reasons too long to expound, but well known to mariners, bring about the replacement of the Paris meridian on our charts by the meridian of Greenwich. They remembered that Louis XIV had solemnly placed at the Paris Observatory that little line of marble which marked the zero meridian of the Observatory, prolonged and marked out so poetically by the Carp Fountain and the centre line of the Lesser Luxembourg. Since then the Paris meridian has had a long and brilliant career, and its abandonment means the death of a bit of France's Past.

Yet we must remember that the time and the zero meridian now chosen to regulate our destinies are not only English. They are also French, since the Greenwich meridian crosses France and passes notably through Saumur. It would have been enough to satisfy the scruples of sensitive patriots to decide that the legal time of France should be that of Saumur, which, being already the equestrian centre of France, is now the meridian centre as well.

And besides, has not Germany adopted the Greenwich meridian, and is it less German on that account?

Some people may have consoled themselves with the reflection that to grow younger by 9 minutes and 21 seconds, on the authority of the law, was a pleasure worth having. And further, since midday has been put back while the time of sunrise remained the same, the length of our mornings has increased by that amount, which is a matter for congratulation if the oft-quoted verse is true which says:

"The morn bears all the pleasure of the day."

The government has made use of the new state of things by abolishing the difference between the times shown outside and inside the railway stations. The question has often been asked why the time inside was always 5 minutes behind the clocks outside the stations. I have been told that this is the reason: When the first French railways were built, the seat of management was at Rouen, the local time of which is just 5 minutes behind Paris. In those days local time was still used throughout France. The time-tables of the railways were naturally based upon Rouen time, and this provisional arrangement survived for a long time. *Se non è vero . . .*

In those happy days which preceded the Great War, the French Government and administration, haunted, perhaps, by the memory of Charles V, busied itself much about the question of time.

Shortly after endowing us with Greenwich time, they decided to force another reform of the same calibre upon us. They imposed a clock-face of 24 hours upon our posts and railways.

Was there any reason to acclaim this innovation with transports of enthusiasm? And could this "reform" be called a "progress"? Opinion is much divided.

In the first place, this reform was nothing new. It was a return to the past. Even among the ancients certain nations counted from 1 to 24 the hours into which they had divided the day, or rather the *nycthemera*, the total of a night and a day. But without going as far back as that, it is certain that in the Middle Ages, and down to the sixteenth century, most of the monumental clocks were divided into 24 hours. Thus the clock taken by Philip the Bold from the market place at Courtrai after the battle of Rosbecque and brought to Dijon was described by Froissart as "that clock, carted to the town of Dijon, which strikes 24 hours in the day and night." And the clock built at Lyon in the sixteenth century by Nicolas Lippyus, of Bâle, also made one turn of its hand in 24 hours. But since that time the inconveniences of the quadrivigintesimal division (whew!) of clocks must have been found out, for the Emperor Rudolph II decided in 1581 to substitute the duodecimal division.

What gave particular weight to that decision is that the emperor took it on the advice of two eminent astronomers who at that time lived at the Court of Prague: Tycho Brahe and Kepler.

The inconveniences of the 24-hour division, apparent even then, have not diminished since.

In the first place, unless the clock-face is not to be overburdened by marking the half-minutes, which would entail much confusion, the marks of the odd hours, 1, 3, and so on, will be opposite no division on the face. Then, if the face is numbered with

Arabic numerals, there will be 39 figures instead of the 15 figures of the duodecimal system. If the numerals are Roman figures, there will be 68. Hence, if the hours are to be distinct, they must be much smaller and therefore less legible. All those whose sight is feeble, and those who cannot examine their watches with a magnifying glass, will therefore object to the 24-hour face. Nor is that all: everybody will have noticed that in public clocks we cannot read the figures, and yet we can tell the time by the angular position of the hands. The Anglo-Saxons, who are practical folk, realise this so well that they often suppress the figures in their large clock-faces. The clock on the Town Hall of Philadelphia has a face without figures, and so have several other English and American monumental clocks. On the other hand, the time would be almost illegible at a distance if, as has been proposed, we decorated our public buildings and stations with 24-hour clock-faces. As regards the striking clocks, which would have to be reconstructed, I tremble to think of the nocturnal symphonies which they would have in store for sleep-lovers, sounding 22, 23, and 24 strokes, not to speak of quarters. It would be a perpetual carillon, especially if we remember that all the clocks rarely chime in unison.

There are many other technical complications which render the subdivision into 24 hours impractical. "Experience, the only source of Truth," according to the great dictum of Henri Poincaré, had already decided to that effect when, many centuries ago, the Emperor Rudolph decreed the division of the clock into 12 hours. Experience has taught the same in countries which, like Italy and Belgium, have recently, and before France, attempted a return to the practice abolished by Rudolph. In neither country have the people decided to adopt the division of the day into 24 hours, and the watches continue to show 12 hours on their faces.

In France it is the same, and not solely on account of the complications we have indicated. There is possibly a psychological reason, based upon the opinion of an important section of the people, the superstitious people.

They do not like the idea of introducing the number 13, an ill-omened and fear-inspiring number, into the hours of the day. And the very hour bearing that number would be the first hour after noon, that exquisite hour which is an oasis of repose in the hard daily labour, the hour when in the languor of incipient digestion we love to mate the brown coffee with the blonde cigarettes. And just then this unwelcome figure comes to spoil the cherished hour with its depressing associations!

It cannot be done. And so, in spite of the administrative ukase, the new quadrivigintesimal division of the day could only be a failure.

CHAPTER V

THE MASTERS OF TIME AT WORK

Telescopes and guns—Louis XIV and Huyghens—The Transit Telescope and the Precise Hour—Time-pieces, from the waterclock to 1228 L—The problem of longitudes—Wireless time signals—The acoustic Vernier—Imagination surpassed by reality.

SOMETIMES, as in 1923, astronomers, watchmakers, makers of chronometers, and physicists assemble in large numbers in the reception hall of our ancient and still vivacious Observatory, among the gigantic bullets and monstrous guns which guard the old and glorious walls. Seen close, the bullets resolve themselves into terrestrial and celestial spheres, and the guns into harmless telescopes. Thus the generally peaceful mood of the High Priests of Time is soon reassured. And among these noble surroundings which the Roi-Soleil sumptuously devoted to the service of the other heavenly bodies, they discuss problems set by the tireless flight of time. There are few matters of greater interest to the philosophers, or of greater importance to the man of action. We know less and less what time really is, or indeed whether it exists at all. I have already quoted the well-known expression of Henri Poincaré: "We for whom time does not exist." Unfortunately his sudden and premature death has come to remind us that, whatever we may call them, there are changes in the external world which we are bold enough to call a real world. And among these changes, the most real and undeniable, the change most painful to the sensitive fibres of our being, is the disappearance of personalities whom we have admired and loved. All this, of course, is subject to our belief in the reality of the external world. But that, one might say, is another question. The answer has not been definitely furnished by the classical philosophers, for one day the wife of one of them, who had certainly read the works of said philosophers, found him in tears, and he confessed that he wept at the thought that perhaps she did not really exist. Happy philosopher! And happy wife!

In short, we know now that we do not know much about Time, which our ancestors claimed to have seized in the grip of their definitions.

Yet, by a strange paradox, we have never known better how to dissect this thing whose essence escapes us. As the identity of time becomes more nebulous, its measurement becomes more exact. With regard to time, Science is in the position of the man who, having married a woman whom he thought he could analyse at first sight, finds, as the years reveal to him her external qualities, that her soul is more and more strange and mysterious to him.

It is not with Time considered philosophically that the chronometric congress sometimes assembled at the Observatory concerns itself. More prosaically, but also more usefully, theoretical and practical questions are discussed which are raised by the determination, conservation, and more and more precise transmission of time. For it is not sufficient to define time exactly, as we have done in the preceding chapter. It must be determined, conserved, and distributed among people who want it—and nearly everybody does to some extent.

It is a curious thing, to be noted in passing, that some of the greatest advances in chronometry, in its widest and etymological sense, have been due to foreigners, furnished by accommodating France with the means of work and research.

One of these was Huyghens, a Dutch citizen, called to Paris by the intelligent eclecticism of Louis XIV, for whom no nationalist barriers existed in the estimation of talent. Huyghens carried out most of his admirable work in Paris. He is certainly the *savant* who contributed most to the advancement of the art of measuring time. His great idea of combining the anchor escapement with the pendulum, all his theoretical work on clocks, his cycloidal pendulum, his equal-force winder, his spiral spring, all these things made him the Newton of clock-making. Another case is that of Daniel Roemer, a

Dane, who was an astronomer of the Paris Observatory, and who, executing and completing an idea of his superior, Abbé Picard, invented and first constructed the Transit Telescope.

Before his time, the hour of noon was usually determined by the so-called method of "altitudes." By means of a telescope mounted on a graduated quadrant of a circle, the sun was observed at a given moment in the morning, and its height above the horizon was noted on the quadrant, as well as the time then shown by a clock. In the afternoon, when the sun in its descending course had attained the same altitude as shown by a new observation with the same instrument, the time shown by the clock was again noted down. It is clear that the middle of the interval between the times shown by the clock corresponded to true noon,[1] or the instant at which the sun reached the highest point in its course.

On any given day, sensibly the same time elapses between the moment when the sun reaches an altitude of, say, 30° until its culmination, and between this culmination and the moment when it descends to an altitude of 30°. Let us imagine, for the sake of a concrete example, that at the first observation of the altitude, the clock, in its regular working, shows 11 hours 2 minutes. If, at the second observa-

[1] This is called "apparent noon" by English astronomers.—*Tr.*

tion at the same altitude, the clock indicated 1 hour 4 minutes, it is clear that true noon occurred when the clock showed 12 hours 3 minutes. Therefore the clock was 3 minutes fast. Or, to use astronomical language, the "correction" of the clock would be "minus three minutes."

That was the method usually employed for measuring time before Roemer's invention of the transit telescope. This telescope is made to turn about a horizontal axis fixed on bearings in an east and west direction.

Under these conditions, as in the case of a field gun which can be elevated to various angles, the transit telescope always moves in the same vertical plane.

That plane, being perpendicular to the east-west direction (the "prime vertical"), must have the north-south direction or meridional direction itself. This means that it contains the culminating points, or points of greatest altitude above the horizon, of all the stars in their apparent daily motion. In short, when the sun is in the centre of the field of the transit telescope, it is true noon for the place where it is stationed. The instrument will therefore tell the hour from a single observation, and does not require several observations, like the method of equal altitudes. But the greatest advantage of the transit instrument is that it turns on a fixed axis, unlike the instruments which had to be turned and displaced. It can therefore be given a greater stability and equilibrium and the precision of the observations is increased accordingly.

The advantages of the new instrument were not perceived at once. As nearly always happens when an idea is new and good, several decades elapsed before the superiority of the device of Picard and Roemer was incontestably established.

In the transit telescope, the meridian is represented materially by a very fine thread, a spider line, a silk fibre, or a fine wire, stretched vertically across the focus of the instrument. There are usually several threads, parallel to each other and equidistant, on each side of the central line. Thus, instead of a single reading there can be a series of double readings, which increases the precision of the observations and diminishes their uncertainty. Each of the double series of readings on both sides of the meridian is equivalent to the employment, in the transit instrument itself, of the old method of equal altitudes. But in this case all the ancient sources of error of this method are practically eliminated by the fixity of the instrument and of the micrometer carrying the cross-wires.

In order to adjust the transit instrument, or in other words, in order to bring it every day into the same orientation and to correct accidental deviations, meridian marks, placed at a great distance, have always been employed. The cross-wire of the telescope is made to coincide with these. Of these marks, one of the earliest was placed at Montmartre, where it is still to be seen, for the adjustment of the transit telescope of the Paris Observatory. They are known as the *mires meridiennes*, and have been provided with improvements which cannot here be described.

It was soon found that observations with the transit telescope of stars whose image is a point is much more exact than observations of the centre of the sun, since the latter has a fairly large disc. Thus the habit gradually spread of determining time by means of star transits. For this purpose, observations are made of so-called "fundamental stars," whose position with respect to the sun is well known. Every day we know beforehand how many minutes and seconds separate the passage of any of these stars across the meridian from the passage of the sun. It is easy, therefore, to determine solar time from the transits of stars.

We have explained above why "sidereal clocks" regulated by the stars do not, except on two occasions in the year, show the same hour as mean solar time clocks. At the Observatory, the clocks we use habitually are sidereal clocks. It is always somewhat of a shock to distinguished visitors who honour us with a call when they notice the impossible time shown by the clocks in our observation rooms. We can guess by their faces the thought they are too polite to express: "Who are these astronomers whose clocks are not even correct?" This unexpressed indignation, which is almost always evident, is only appeased on our giving the explanations which our visitors were shy of demanding, for fear of covering us with confusion.

The master-clocks placed in the vaults of the Observatory, to which we shall refer hereafter, are regulated by sidereal time.

After these remarks let us return to the transit telescope, which gives mean time as already defined.

Among modern improvements of this instrument we must specially mention the following.

Formerly, astronomers took the trouble of keeping the axis of the transit telescope always in the meridian by means of meridian marks. This involved a constant adjustment of the screws and interfered with stability. Nowadays they prefer not to touch the telescope, but to determine from day to day the amount by which the optical axis departs from the meridian.

As the precision of the results increases, other causes of error reveal themselves. It has been found that every observer has his own way of timing the instant of the passage of a star over a cross-wire. One will see it pass before its real passage, another after it, and the discrepancies are very variable. They are fairly constant, however, in the same observer, and constitute what is known as the astronomer's "personal equation." This shows that the expression "personal equation" has a sense and origin far removed from its current use. But what would become of us, and particularly of the printers, if it were forbidden to employ current phrases in a sense other than the original, even when they adorn the landscape of eloquence so nicely!

Another cause of error which has been observed is called the "equation of magnitude." It consists in the fact that the appreciation of the passage of a star over a cross-wire depends upon its apparent brightness, or what is called the "magnitude" of a star. Corrections are applied to eliminate the causes of this inaccuracy.

In stars round the pole of the heavens ("circumpolar stars") the apparent movement of the star in the field of the telescope is sometimes from right to left and at other times from left to right. This also influences the precision of the observations, but it can be corrected by using a reversing prism as used in microscopes, and making the stars always pass in the same direction.

This various cause of error, and others as well, have been eliminated, or at least much reduced, by attaching "impersonal" micrometers to modern transit instruments. Formerly, the passage of a star was taken "on the wing" so to speak. In the impersonal micrometer method, the astronomer simply bisects the star with a movable cross-wire which he moves by means of a screw, so that it travels across the field at the same pace as the star. The moments at which the cross-wire, and hence also the star, passes across the middle of the field and certain accurately measured positions to the right and left of it are automatically registered by an electrical arrangement with reference to the clock facing the instrument, in seconds and hundredths of a second.

That is the last word in astronomical determinations of time. It determines it to within three-hundredths of a second. It seems difficult to increase that precision still further. It is now limited by causes independent of our instrumental progress, notably by the continual undulations and movements of the atmosphere which make the passage of stars shaky and imperfectly uniform.

Once the time has been ascertained by observation of the stars, it must be conserved. That is what is done by clocks and other time-pieces.

In ancient Rome, rich patricians had a slave specially charged with getting the time from the sundial in the public square and bring it back to their masters. What became of the hour on the way from the square to the house? And what about the people who had an appointment at the Forum at a certain hour, when the sky was overcast? Even in those days, for a wonder, parliamentary orators were prolix, and so political oratory led to the *clepsydra* or water-clock. To limit the loquacity of the speakers, water-clocks were provided with a pointer driven by a small mill-wheel. This led to the expression: "You are trespassing on my water," used in the Roman senate by the orators against each other. Latin authors even report that the employees charged with the care of the water-clocks surreptitiously favoured their friends and hindered their adversaries by altering, by means of concealed bits of wax, the size of the hole through which the water flowed. Nowadays, fortunately, political morality is less unscrupulous. And we have also better means of ascertaining and preserving the correct time.

Clocks of precision date from the time when Huyghens had the ingenious idea of combining two mechanisms already in use: the pallet escapement and balance wheel on the one hand, and the pendulum on the other hand. His application of the free pendulum to weight-driven clocks made a sort of revolution. The invention of the anchor-and-recoil escapement by Clément was an important improvement. Several others have been effected since then, including

Graham's dead-beat escapement, and those of Lepaute and Reid. Let us mention that one of the most widely used escapements of the eighteenth century was the double-hook escapement, invented, as the Academy of Sciences announced after due enquiry, by M. Caron, junr., who subsequently rose to fame as Beaumarchais. So true it is that talent will out, whatever the occupation to which one is born.

To sum up, all mechanical clocks since Huyghens consist of three essential organs: (1) the motor, whether consisting of weight, spring, or electric motor; (2) the regulator, a pendulum or balance wheel; and (3) the escapement.

The motor keeps up the motion of the clock, but it would tend to be accelerated and irregular without the escapement. The latter is a moderating mechanism or equilibrator, whose function is to create between the motor and the pendulum a reciprocal action such that, on the one hand, the pendulum retards the escapement and makes the motive power uniform, while on the other hand the latter is uniformly transmitted to the pendulum so as to keep up its oscillations. It is evident that the quality of the escapement involves that of the whole clock.

Variations of temperature affect the length of the pendulum. Several systems of compensation have been invented to remedy this. The oldest and still the best is that of Graham. It consists in attaching a tube containing mercury to the lower end of the pendulum. When the temperature rises, the rod of the pendulum lengthens, which loosens its centre of gravity. But, on the other hand, the mercury also expands and rises in the glass tube containing it. This raises the centre of gravity of the mass of mercury. It is easy to calculate the relative dimensions of the metallic pendulum and the mercury in order to make the raising of the centre of gravity of the latter compensate exactly the lowering of the centre of gravity of the rod.

Changes in barometric pressure also disturb the rate of the clock. Pressure compensations have been devised. But finally it has been found preferable, where great precision is desired, to shield the clock from changes of both temperature and pressure by enclosing it in an airtight box under a constant pressure and placing the box in an enclosure with a constant temperature.

This procedure, which is now becoming universal, constitutes the last improvement in astronomical clocks, and renders possible a degree of precision unknown a few years ago.

In this respect, the time-service of the Observatory has, under M. Bigourdan's wise direction, become a model which foreign observatories endeavour to imitate without complete success up to the present.

Four clocks, all masterpieces of precision, are immured in closed chambers in a vault situated 90 feet below the floor of the Observatory, and these clocks are entrusted with the preservation of time as given by the stars. All day long, and all the year round, the clocks are at a perfectly constant temperature. Near the surface, the ground follows more or less the vicissitudes of the temperature of the air. But the further we go below, the less becomes this correspondence. Some 60 feet below ground there is no change, and we are in the "level of constant temperature." Our four master-clocks in that layer are therefore completely shielded from the changes caused by temperature in the movement of clocks and watches. That is not all. The variations of atmospheric pressure are also suppressed, because the four master-clocks are placed in hermetically sealed enclosures, where a constant pressure reigns. Nobody goes near these precious instruments. They are wound up electrically at a distance, and electrically they transmit to the other clocks of the Observatory, and to the world in general by the magic of wireless signalling, the time which they guard as a precious treasure and yet distribute so generously.

But, somebody may ask, why four clocks and not one? That is in order that they may watch and control each other, and so that any accidental variation of one may immediately be pointed out by the others.

The most remarkable of these clocks is probably that which bears the number 1228 L. It has been going for four years without a stop and without being cleaned. Yet it is accurate to within two-hundredths of a second after 48 months, which means that in that interval it has deviated by less than that amount from a uniform advance.

That clock, let us repeat, shows sidereal time. It was first provided with a Graham escapement, which was subsequently exchanged for an improved Reid escapement. Then it was installed in the vault of the Observatory, where it has been going since the 24th December 1919. In April 1921 the electric contacts were cleaned and the pressure was adjusted to 603 millimetres of mercury. It has not varied since. Since June 1921 it has become the master-clock, and it synchronises electrically the secondary clock charged with controlling most of the Observatory clocks. This experiment, unique in its duration, will be continued, for the clock shows as yet no sign of fatigue.

Its regularity is quite exceptional. I remarked above that the "correction" of a clock is the amount which must be added to the time shown by a clock in order to obtain the correct time. If we put down the "corrections" of a clock for two consecutive days and take the difference, we obtain what is called the "rate" of the clock. In other words, the "rate" is the amount which the clock gains or loses per day as compared with ideally correct time. An absolutely perfect clock would have a constant zero "rate." On the other hand, it can be perfect and yet have a considerable "correction," since the "correction" may result from a wrong original timing or setting, and may have nothing to do with the "rate," which is the only essential quality of a perfect time-piece.

To give some actual figures, I may here quote for certain periods the mean rates of the clock 1228 L, in other words, the quantities by which it has, on the average, advanced every day since May 1921:

Period.	Rate.
May 1921 to 18th October 1921	0·069 sec.
19th October 1921 to 1st February 1922	0·083 ,,
2nd February 1922 to 15th March 1922	0·090 ,,
16th March 1922 to 31st August 1922	0·100 ,,
1st September 1922 to 15th February 1923	0·113 ,,
16th February 1923 to 15th March 1923	0·125 ,,
16th March 1923 to 30th June 1923	0·120 ,,
1st July 1923 to September 1923	0·110 ,,

Thus, after having advanced more and more for two years with a slight acceleration, this clock has become stationary in its rate since the spring of 1923.

What is very remarkable is the *regularity* of the rate of this clock, that is, that the rate varies very little, and in a very uniform manner. From April 1921 to April 1923, the acceleration of the rate was on the average less than a 200,000th of a second per day. This means that the precision with which such a clock preserves the time is superior to that with which astronomers determine it. This implies that in all scientific practical circumstances—and these are the most numerous—in which it is required to find an interval of time, a precision is now obtainable which could not have been expected a few years ago.

The progress made by these French clocks is such that numerous other observatories have made a point of acquiring them. Even Great Britain, always so proud of her personal methods, has entered upon the path opened by our astronomers and instrument-makers.

From the above figures it is clear that the rates of the master-clocks of the Paris Observatory, accumulated for several days, are more certain than the times determined by astronomical methods. The astonishing result is that the rôles are now frequently reversed at the Observatory. Formerly, the astronomer supervised the clock, and corrected it by celestial observations. But nowadays it is often the clock which supervises the astronomer and rectifies his results. In any case, when bad weather interrupts transit observations for several days no inconvenience is caused, for the marvellously regular hands of the master-clocks completely take the place of the hidden stars.

Yet we must not exaggerate. It is always the astronomer who has the last word. For he relies on the perfect regularity of the diurnal motion of the earth, whereas the most perfect clock does not always keep the same rate of going. After ten days, or even a hundred days, the telescope will still give the time to within a fiftieth of a second, while the clock will give it with an accuracy which diminishes with time. It sometimes has even accidental discrepancies, as happened to that masterpiece 1228 L, which has sometimes, and without apparent reason, varied suddenly by 3 to 6 hundredths of a second. These small changes, which formerly would have gone unnoticed, were immediately revealed by comparison with the other clocks placed in perfect conditions of temperature and pressure as described above.

In their present stage of development, the determination and conservation of time do honour to modern science and to the glorious establishment which has brought them to a point of perfection as yet unequalled elsewhere: our ancient and well-established Paris Observatory.

The time thus precisely determined would be a useless luxury, a curiosity with no attraction but that of difficulties overcome, if it were only preserved in observatories and embodied there in chronometers, clocks, and other "time-pieces."

What is of no less importance, or, rather, what gives the whole procedure what importance it has, is the distribution of that time to all who need it: public offices, railways, navigators, geographers, scientific men, and private citizens.

The fundamental problem of the distribution of time is, therefore, the compulsory outcome of its determination and conservation. Above all, seamen must know the exact time. Of the two co-ordinates which determine their position at sea at a given moment, latitude and longitude, the former is given by astronomical observations of the sun and stars with instruments kept on board ship, and particularly the sextant.

It is a well-known fact, demonstrable in the simplest manner, that the latitude of a place on the globe is the angular height above the horizon of that region of the sky near the Pole Star known as the Pole of the Heavens. At the equator, the Pole is seen on the horizon. Its altitude above the horizon is then zero, and so is the latitude. At the poles of the earth, on the other hand, the celestial pole is overhead, in the zenith. The height of the pole and the latitude are then both equal to a right angle, or 90°. Under all intermediate latitudes the same equality between latitude and altitude of the pole holds good. Now all mariners are provided with tables showing the angular distance of the sun and stars from the pole from day to day. It follows that if they observe one of these bodies at its daily culmination and determine its altitude above the horizon by means of the sextant, the latitude can be immediately deduced.

The problem of longitude is quite different. It is reckoned from east to west from a certain initial meridian which, since the official (and perhaps regrettable) renunciation by France of the Paris meridian, is for the whole world that of Greenwich.

Time being regulated by the course of the sun and the stars, as already explained, a given star will, at the same physical instant, be more or less above the horizon according to its position to the east or west of another. It follows that if two watches indicate the true time according to a certain star, they will not show the same time everywhere. This time is later and later as we proceed towards the west, for the sun rises and culminates later and later. When it is true noon ("apparent noon") on a given meridian, it is true midnight along a meridian passing through the antipodes. Since the earth's circumference is divided into 360° and the half-circumference into 180°, it follows that 12 hours correspond to a difference of longitude of 180°, one hour to 15°, one minute of time to 15 minutes of arc, and one second of time to one second of arc, etc. Hence, also, every degree of longitude separating two places means a difference of 4 minutes in time. It is evident that the problem of longitudes amounts to a determination of the difference between the local time and the time of a prime meridian which nowadays is that of Greenwich.

Navigators measure local time with the sextant, using astronomical observations analogous in principle to those already described in the case of observatories, though less exact. Knowing the true local time, the mariner, in order to deduce his longitude, need only know Greenwich time at the same moment.

To do this, mariners had, up to the end of last century, only one means, viz. to take this Greenwich time about with them. For this purpose they used time-pieces called "chronometers," having a very regular rate, which were timed on departure and trusted to vary as little as possible in a long voyage.

It was essential that these ships' chronometers should keep time as faithfully as possible, and gain or lose very little. If they failed, the ship would risk losing its way and running a thousand dangers. A very small error of the chronometer would involve considerable errors in the estimated position of the ship. These errors are greatest near the equator. At or near the poles of the earth an error of several hours, not to speak of minutes, would only mean a small mistake in miles. It would mean a large mistake at the equator. Along the equator, where the day of 86,400 seconds corresponds to 24,000 miles, every second of error in the clock means about a third of a mile in distance, and every minute means 15 nautical miles.

In our latitudes, the difference is rather less, though still considerable. Thus, at Paris, between the Point-du-Jour and the bridge of Charenton, which are separated by 12 kilometres, there is a difference of longitude of about 37 seconds. The sun rises 37 seconds earlier at Charenton than it does at the Point-du-Jour.

All this shows that the problem of the determination of longitudes was closely linked with that of conserving the time by means of a perfect chronometer. Many historic improvements of clockwork were suggested and evoked by the needs of navigation and stimulated by the competitions organised by the British Admiralty and the French Marine Department for this purpose.

Recently, owing to wireless telegraphy, the problem of longitude has changed completely. It is no longer bound up with the conservation of time, but with its distribution. Ships' chronometers, or at least those which are meant to keep Greenwich time, lose their importance as wireless signalling develops, and we can foresee the time when they will cease to be indispensable.

Wireless telegraphy can, indeed, transmit Greenwich time almost instantaneously to ships on all oceans, so long as they are provided with a receiving outfit. Hertzian waves are propagated with a speed of 183,000 miles per second, which is the velocity of light. They therefore take barely a fifteenth of a second to reach the antipodes, half-way round the earth. The navigator, therefore, wherever he may be, is sure of receiving the time of the prime meridian with a precision considerably above that with which he can himself determine local time with the sextant.

Before this evolution, which is a sort of revolution, the determination of longitudes at sea was limited in accuracy by the precision of the chronometer on board, and that precision diminished with the length of the voyage. To-day it is different. The precision with which the time distributed over the sea arrives at its destination is practically always the same—and it is excellent.

How has this simple and beautiful result been attained and brought to its present perfection? I wish to indicate it briefly here.

The first practical attempts at long-range wireless telegraphy go back to 1899, for in that year Mr. Marconi, with the aid of the coherer of Branly and Lodge, succeeded in receiving at Boulogne-sur-Mer some Hertzian signals sent out from Dover, 28 miles away.

I need not enumerate the subsequent steps. To come to the point, it was in 1908 that the Bureau des Longitudes passed the resolution, which was at once handed to the government, "that a service of time signals be installed as soon as possible at the military radiotelegraphic station of the Champs de Mars." The War Minister soon provided the funds and the projected installation was organised under the direction of Commandant Ferrié (now General Ferrié) whose name is now inseparable from improvements in this domain.

Completed at the beginning of 1910, the installation was temporarily put out of action by the floods which are still remembered. The damage, however, was soon repaired. On the 23rd May the service of time signals was begun which has since continued without interruption. On the 22nd June 1910, the Bureau des Longitudes, under the presidency of Henri Poincaré, solemnly inaugurated the Eiffel Tower Time Station in order to emphasise the fact that our powerful wireless post, besides fulfilling its purely military purpose, would henceforth be a prop of science as well as an auxiliary of national defence.

The wireless distribution of time signals by the Eiffel Tower worked so satisfactorily and usefully that the Bureau des Longitudes felt called upon to bring about an international understanding for its extension and improvement.

A first conference, of a purely technical nature, assembled in October 1912 at the Paris Observatory. On a basis established there, a second conference was held in the same place on October 20th to 25th, 1913, at which 31 different States were represented.

It was decided that a certain number of wireless stations already in existence or yet to be established, distributed all over the globe, should be given the task of distributing wireless time at hours fixed beforehand. Thus the navigator, the geographer, the geodetic surveyor, and the traveller, wherever they might be, would be able to receive the time at least once a day. It was arranged that the time transmitted by all the stations should be that of the Greenwich meridian. Whoever received it would then be indifferent as to where it came from.

But there was an essential condition to realise. All the participating States would have unanimously to adopt the system of hour sectors already experienced, which connects the official time of all countries in a simple manner with Greenwich time.

At the time of the Congress, a few months before the War, several nations still obstinately refused to join this plan of unification. Ireland, for instance, still kept Dublin time,[1] and did not wish to let it go. This proves that in one point, at least, English

[1] Dunsink Observatory.—*Tr.*

domination was not particularly tyrannical. Greece did not want to abandon the Athens meridian. I pass over others of equal importance.

The first result of the Congress of 1913 was to break down some of these resistances. Greece joined the sector system in July 1916, Chili in September 1918, Ireland on 1st October 1916, Poland in September 1916, Siam, the Argentine, and Uruguay in 1920. There are still a few countries opposed to this levelling and jealous of their temporal independence, notably several Central and South American republics. In Europe, unless I am mistaken, only the Netherlands remain outside the Greenwich sector system, and still use Amsterdam time, which is 20 minutes ahead of Greenwich time.

Yet the recalcitrant countries can use the time signals sent out by the standard time stations by adding a small correction which is the same always.

At first the Congress of 1913 recommended that Greenwich time should be sent out by wireless from the following stations, distributed all round the globe. In this list, the hour of Greenwich mean time is given after every station :

Paris, 6 and 10.
San Fernando (Brazil), 7 and 16.
Arlington, U.S.A., 3 and 17.
Manila (Philippines), 4.

Mogadiscio (Somaliland), 4.
Timbuctoo, 6.
Norddeich (Germany), 12 and 22.
Massowah (Eritrea), 18.
San Francisco, 20.

This ambitious programme was not carried out. The war supervened and gave the Governments more urgent matters to deal with. Even now there are certain more essential matters on which it is difficult to come to an agreement.

But the fact that in this particular the resolutions of the 1913 Time Congress have not materialised is perhaps not an unmixed evil. It was believed at that time, and with good reason, that it was necessary to have stations distributed over the globe in order to distribute time everywhere by wireless. To-day this necessity no longer exists. Thanks to technical progress, especially the triode valve, the range of transmitting stations, and the sensitiveness of receivers has increased at a rate undreamt of ten years ago. We can now foresee that in the near future even a medium-powered station will suffice to send the necessary time signals right round the earth.

Recent tests have shown that the transmissions of our Eiffel Tower, as well as those of the Doua station near Lyon, among others, easily reach the antipodes and can be received in Australia. It is therefore only half a misfortune that the establishment of the time stations proposed in 1913 has not been carried out according to programme.

For the present, and until better times, there is an organisation elaborated by the same Congress which has been of the greatest service to science and all those who require wireless time. I speak of the International Time Office (B.I.H., *Bureau International de l'Heure*) directed by M. Bigourdan, which, under the guidance of that eminent scientist, has, since its origin, developed a fruitful and laborious activity.

The Eiffel Tower radio station is, as a time-signalling station, connected with the B.I.H. The nature and times of its various transmissions have undergone several modifications from time to time.

Among these transmissions there are those which are called *normal*, and others which are called *occasional*. The former are those which function regularly and will be continued. The others are for tests or special uses, and only last a few weeks as a rule.

These signals consist of a series of dots and dashes according to a prearranged plan well known to those interested, which need not be detailed here. These coincide with such and such minutes and seconds.

The automatic character of these signals is secured by an electric connection between the transmitting station of the Eiffel Tower and the master-clocks of the Observatory, which themselves set going the transmissions at a distance. I add, in order to avoid the astonishment of those readers who read the technical press about these matters, that the Eiffel Tower station is designated by the letters FL, which is a sort of pun.

Let me also add, without mentioning other details, that the powerful wireless station of the Croix d'Hins, near Bordeaux, constructed by the American Army, known by the letters TY, as well as the Doua station YN, also contribute by their time signals to the researches of the B.I.H.

What is the object of the "occasional" signals issued by these stations? It is work of the highest interest. In 1921, for instance, the Eiffel Tower emitted occasional signals at prearranged times in order to help the work of a frontier commission in Syria. Similar signals assisted the French and British geodetic missions which fixed the frontiers of the German African possessions divided between Britain and France.

Formerly, the explorers and geographical officers entrusted with such work had to be satisfied with the time given by the chronometers they had brought. That time underwent all the vicissitudes of travel, and in the Black continent, for instance, often showed discrepancies of over 10 minutes. Now such an error would, on a map, mean an uncertainty of some 200 miles. What an immense progress in cartography and in territorial delimitations which so often, by their uncertainty, have brought about diplomatic conflicts and even wars!

We must not flatter ourselves that these cannot find other excuses. But if it had only suppressed one of them, the determination of longitudes with the aid of wireless transmission would deserve our admiration. It is thus that the Franco-Spanish frontier in Morocco was recently fixed. That was also the method used in the Franco-German agreement (how long ago it seems!) concerning the Congo and Cameroons before the war. Thus also, if I am not mistaken, was the Franco-Italian frontier in Tunisia determined.

The two powerful wireless stations at Lake Tchad on the one hand and Madagascar on the other hand will contribute their time signals to this work of geographical precision, in other words, of good diplomacy.

The amateur who receives the time signals with a "listening-cap," and the wireless enthusiast provided with simple apparatus but no arrangements for exact measurement, use what astronomers call the "eye-and-ear method" for receiving the correct time. It consists in observing the hand of the clock or the chronometer whose correction is to be found and noting, at the instant when the hand points to a given second, by how many seconds or fractions of a second the little noise of the time signal precedes it or follows it.

In observatories and physical laboratories this method is replaced by a method of automatic registration. The precision attained in these methods is such that, in certain recent determinations of longitude it has been found possible to use the results for determining the velocity of propagation of the Hertzian waves themselves (a prodigious velocity, amounting to 183,000 miles per second) with a remarkable precision in spite of the relatively small distance of the two stations.

And this leads us to say something about one of the most astonishing applications of the transmission of time.

It has been known for some years, from astronomical observations of extreme precision, that the latitude of the various parts of the earth is in general not absolutely fixed. By systematic researches made in different observatories distributed all over the globe, it has been established that these variations of latitudes are real and that they balance each other in some way on the two sides of the globe. It is concluded that the poles of the earth, that is, the points at which its surface is intersected by its axis of rotation, undergo periodic movements whose curve of displacement can be very exactly traced on the map.

What had been thus done as regards latitude could not until recently be repeated for longitude. Wireless time signals will soon enable us to fill up this gap. The International Time Office and the Bureau des Longitudes have made up a plan for carrying out systematic determinations of the longitude between stations similarly distributed over the earth. The periodic or accidental differences of these measurements will give valuable indications concerning the movements of the earth's crust. In particular, they will furnish material for testing the curious theory of the geologist Wegener, according to which the continents, instead of being fixed, are slipping on the plastic and more or less fluid stratum which forms their support.

It is clear that these ultra-precise determinations of longitudes thus projected require the comparisons to be made with extreme exactness.

That is the reason why, besides the ordinary time signals, the signalling stations send out so-called "scientific" signals, intended for much more exact comparisons.

These signals enable an operator working on the eye-and-ear method to obtain an accuracy about five times greater than is possible by the ordinary method, that is, to know the time within a fiftieth instead of a tenth of a second.

The reception of the "scientific" time signals necessitates the employment of the curious "method of coincidences," the principle of which I should like to explain without much technical detail.

Let us suppose that my eye is fixed on my own clock and I listen to the beats of its seconds hand while I also listen to the beats of the time signal from the Observatory in the telephone on my head. Let us also suppose that the directing clock of the Observatory is so regulated that between two successive beats there is not the interval of a second, as in my own clock, but a second less a fiftieth, that is, 49 fiftieths of a second.

I assume that the Eiffel Tower emits a series of these point-signals at this shorter interval. Let the first of these ticks be emitted, say, at 1 hour, 30 minutes, 0 seconds exactly. Generally speaking, this first tick of the Eiffel Tower will not coincide with one of the ticks of my clock, nor with the following ones. But since the ticks of the wireless signals are a little faster than those of my clock, I shall find that the ticks will gradually come closer together, and at a certain moment I shall hear the ticks of my clock and those of the Tower *at the same time.* I took the precaution of counting the ticks of the Tower as I heard them. Let us suppose that the coincidence happens at the eighth tick, and that at the moment of the coincidence my clock shows 1 hour, 30 minutes, 13 seconds, for instance.

The coincidence took place when the time at the Observatory was 1 hour, 30 minutes *plus* eight times 49 fiftieths of a second, that is, at 1 hour, 30 minutes, 7·84 seconds. My own clock is, therefore, 5·16 seconds fast.

Such is this ingenious "method of coincidences" which corresponds in the measurement of time to measurements of length by the "vernier" so well known to our engineering students, carpenters, and mechanics.

Thanks to these signals, there is nowadays no wireless amateur, however modest, who is not in a position to obtain the time from the Observatory with extreme accuracy, which, unfortunately, does not avail to stop its relentless flight.

But we love, like all the sick people whom Molière has studied so well, to have exact knowledge of the ills of which we die. Time is one of these, and is of all the most inexorable.

The ancients knew it as well as we all do, and there was a certain melancholy in the poetic cult devoted to the Hours, daughters of Zeus. But the reality unveiled by science infinitely surpasses the greatest flights of our poor imaginations. The ancients could never have dreamt that one day, in the heart of Gaul, from the top of a steel column of a thousand ells, invisible messengers, the waves which vibrate 100,000 times every second, would rush across the oceans and silently chant the names of the Hours into the ears of struggling mariners.

SECOND PART

CHAPTER VI

EINSTEIN OR BERGSON?

The Relativity of Time—Einstein's demonstration and Bergson's objections—For and against—Physics and metaphysics—The solution of the conflict—A new demonstration concerning the point at issue—Reciprocity of points of view—Examination of the arguments of some authors.

THE most drastic revolution in our ideas of time and its measurement is undoubtedly that brought about by Einstein. Not to deal with Einstein's ideas of time in a book about it would be as absurd as omitting to speak of the sun in discussing daylight.

We shall therefore endeavour to bring some clearness and precision into the questions raised by Einstein's conception of time. This is all the more necessary since, during the four or five years that the theory of relativity has been before the educated public, an ever-growing confusion has reigned with regard to it.

We have seen eminent physicists, many of them distinguished by important discoveries, accuse each other of having failed to understand Einstein's theory. We have seen a whole literature grow up, dozens of volumes of very varying degrees of merit, devoted either to the refutation of Einstein himself—these are the most numerous—or to the criticism of those who had favourably commented on Einstein, or had criticised him.

It is a sort of Tower of Babel, and one of the most illustrious members of the Academy of Sciences, annoyed with all this printed matter and these contradictory arguments, where claims on both sides are equally categorical, said the other day in a disappointed tone: "Nobody understands it now."

In the following pages, which are the fruit, however imperfect, of a long meditation, I shall try to get some order into this "horrible hotchpotch" where physics and metaphysics meet and quarrel. I cherish the hope that on reading them even the reader least versed in scientific matters and elementary mathemathics will no longer be able to say: "Nobody understands it any longer." He will, I am sure, be in a position to form a decided and reasoned opinion concerning the conclusions he should finally draw from the controversy.

The whole Einsteinian synthesis concerning the relativity of time is founded upon the idea he has developed that the duration or time interval separating two given events is not the same for two observers of these events if these observers are moving with different speeds. This inequality of results obtained by two observers undergoing a relative displacement is itself based on Einstein's affirmation that *two events* *which are simultaneous for one observer are no longer simultaneous for another observer if he is moving with respect to the former.*

This relativity of simultaneity is the foundation of Einstein's whole theory. It is its very corner stone. Also, it is in direct contradiction with classical science, with Newtonian science. According to the latter, simultaneity has an absolute meaning, that is to say, it maintains that if two events are simultaneous for one observer they are also simultaneous for other observers, whatever may be their speeds.

That is the essential point, the crucial point, the kernel of the whole question, from which all the rest follows. It is the division between Einstein's theory and the classical science founded by Galileo and Newton.

At the head of a very remarkable study of these controversies[1] M. Jacques Maritain recalls Plato's fine dictum that the philosopher must be prolix concerning principles, since all the rest depends upon them.

Let us therefore not be afraid of being prolix concerning the principles of the Einsteinian synthesis, so long as we do not abandon our ideal of clearness.

What is the real question at issue? It is really

[1] *Nouveaux Débats Einsteiniens*, in the Revue Universelle of 1st April 1923.

to know whether simultaneity is relative, as Einstein maintains, together with his partisans, the most authoritative of whom in France is M. Paul Langevin, professor at the Collège de France. It is to know whether those in the other camp, which comprises illustrious and eminent men like M. Bergson and M. Jacques Maritain, are right in declaring that simultaneity is *not* relative.

M. Bergson has devoted a whole book[1] to the exposition of his views on this question, and to the detailed refutation of what he considers an initial and essential error on the part of Einstein. In this book, a work of great persuasiveness and literary distinction, the famous philosopher, whose profound scientific knowledge cannot be denied, has set out to prove that Einstein's relativity of simultaneity is but a mirage, an artificial and false image of the phenomena, and that the simultaneity of two events has an absolute value, which is accessible to all classes of observers. In the essay to which we have alluded, M. Jacques Maritain has deliberately ranged himself on the same side of the barricade and has supported Bergson's reasoning with a vigorous and attractive dialectic.

This conjunction and agreement of the two men is the more remarkable since they are equally armed with physico-mathematical attainments and repre-

[1] *Durée et Simultanéité.* Alcan, Paris.

sent in France the two opposite poles of contemporary philosophy.

That two men of such eminence, and also profoundly different from each other, should be in agreement in the refutation and complete negation of an assertive and fundamental demonstration of Einstein, and by reasoning which, after all is said and done, appears to be logically irrefutable, appears surprising in the first instance. For after all, there may be endless and fruitless discussions on the best structure of a government, on the most perfect form of art, or on some metaphysical or ethical problem, and nobody will be astonished. But that in the present case, where it is only a matter of logical deductions from *facts* which none of the adversaries think of contesting, that in a case so free from ambiguity such eminent spirits should range themselves without a possibility of conciliation in the categorically opposite positions they have taken up, while appealing solely to reason and to the same facts, is a disconcerting phenomenon, and probably without a precedent.

It appeared to me that there must be some great misunderstanding here, some monstrous equivocation, which need only be discovered and unveiled to bring everything into agreement and to unite Bergsonians and Einsteinians on a common ground of conviction.

I believe I am able to show that that is indeed the case, and to put my finger on the origin of all this confusion. The reader will judge from what follows whether my view is correct.

Einstein maintains and demonstrates that two events which take place *at the same time* for a given observer do not take place *at the same time* for an observer in a state of motion with respect to the former. M. Bergson and M. Maritain maintain and prove, on the other hand, that Einstein's reasoning is false or specious, and that two events which are simultaneous for one observer are necessarily simultaneous for all others. That is the position of the question and those are the theses before us.

Before going any farther it is well to define the sense of the expressions "at the same time" and "simultaneous," and to avoid an equivocation, which, indeed, neither Einstein nor his adversaries use as a refuge.

It is very easy to say, like certain learned persons, that the disagreement between Einstein and either Bergson or Maritain is simply due to the fact that "these have not understood Einstein." It is easy to say it, but it would be better to prove it. We shall see later on that the only mistake of MM. Bergson and Maritain was, I will not say, in understanding Einstein too well, but in adhering too closely and exactly to the letter and text of a single one of his proofs. But we must not anticipate.

When I say that for me two events take place at the same time, or are simultaneous, what exactly do I mean? If I hear two clocks, distant from each other and from myself, striking half-past twelve, do I say that they struck at the same time? No, not if I know that I am near one clock and far away from the other. For I know that sound is not propagated instantaneously and that it takes about five seconds to cover a mile. If, therefore, I am near one of the clocks and a mile away from the other, the fact that I hear their strokes at the same time will induce me to say: "The two clocks did not strike simultaneously, but the far one struck five seconds before the near one."

From the fact that two sensations are simultaneous we can, therefore, not conclude that the events which caused those sensations were also simultaneous. I could only draw that conclusion if the agent which transmits the news of the event to my sense organs—in this case a wave of sound—was instantaneous and had an infinite velocity. Now we do not know in nature any mechanical or physical agent of transmission or any radiation endowed with an infinite speed. The swiftest actual agent of transmission known is light, which, like electricity, is propagated with a velocity of about 183,000 miles per second.

There is, therefore, no phenomenon known in nature which enables us to assert that when we perceive two distant events at the same time, these events take place at the same time.

There is, however, one case in which I can assert that events perceived at the same time take place at the same time. It is when I am at equal distances from both events and when the agent of transmission has the same speed in both directions. In current everyday practice, the distances across which we operate are so small, and the speed of light is so great, that it reaches us *almost* instantaneously from all terrestrial objects within view.

That is why we are accustomed to say that two events, such as the "dead-heat" arrival of two horses at the winning post, are simultaneous when we see them at the same time. Similarly, we say that two distant clocks show the same hour if we see their respective hands on the same division of the dial at the same time.

This simplicity of the notion of simultaneity, which agrees with custom and common sense, ceases as soon as we consider objects sufficiently far away to make light spend an appreciable time before reaching us. That happens in the case of the stars.

When I observe in the spectroscope an eruptive protuberance which suddenly raises its pink flame on the edge of the sun, and when, with the intention of consulting my watch as to the exact time, I drop it in my hurry on the observatory floor, am I right in saying that the protuberance burst forth on the sun at the moment when my watch dropped on the floor? Assuredly not. I know, in fact, that light takes eight minutes to reach us from the sun. The protuberance therefore burst forth eight minutes before my watch fell, and not at the same time. In order that I may feel justified in regarding the two events as simultaneous, I must have observed the appearance of the protuberance eight minutes before the fall of my watch.

There are certain experiments nowadays performed by physicists in their laboratories which are so precise that the time taken by light to traverse even a few yards or feet cease to be negligible.

By analogy with what we said just now concerning our two clocks and their being equidistant from the observer, we may rigorously define the simultaneity of two events A and B as follows: These two events are simultaneous when they are seen at exactly the same time by an observer placed at equal distances from both. This definition is perfectly in agreement with the reality and the nature of things provided that light takes the same time to traverse the distance separating A from the observer and the distance separating B from the observer. These two spaces are equal, by definition. In order that our definition of simultaneity should be free from objection it is therefore sufficient that the speed of light in passing from A to the observer should be the same as its speed in passing from B to the observer. In a word, it is necessary and sufficient that the speed of light be the same in every direction drawn from the observer.

Now that the speed of light is the same in every direction with respect to a given observer, whatever his state of rest or motion, follows from all electromagnetic experiments, and notably from the celebrated experiment of Michelson. It is a result founded on many concordant experiments, and contradicted by none. This result, which we must consider as established, constitutes what Einstein calls the principle of the constancy of the velocity of light. It is not, as certain commentators believe, a theoretical and *a priori* axiom or an arbitrary convention, but is an expression generalised from a series of experimental facts which are not contested.

Einstein says, "I call two events *simultaneous* for a given observer when they are perceived or seen at the same time by that observer while he is equidistant from both"; and when he puts forward this definition which he, much too modestly, calls a convention, he is in agreement with usage, with common sense, and with the best-established physical facts.

This definition of physical simultaneity is indeed readily admitted by M. Bergson, who calls it "simultaneity at the instant," and by M. Maritain. They do not worry M. Einstein on that score. The only thing they contest is that Einstein has really proved that simultaneity thus defined must be relative. They maintain, on the contrary, that simultaneity thus defined is absolute and exists as such for all observers, whoever they are.

In order to get into touch with their reasoning, and in order to avoid a fallacy, a very elementary point must be made clear: If two events are by definition simultaneous for an observer equidistant from both who perceives them at the same time, it is evident, or at least unanimously admitted, that these two events will also be simultaneous for other observers placed at a certain fixed distance from the equidistant observer, and at rest with respect to him. Knowing that they are not at equal distances from the two events, these observers will make the necessary correction, that is, they will imagine themselves at the place occupied by the first observer. This also implies that these observers will be able to consider two events simultaneous which they do not perceive at the same instant, since they will take account of the time taken by light to traverse the distance separating them from the equidistant observer. The above definition, therefore, applies to all observers having no velocity with respect to the observer who is equidistant from the two sources of light.

In this point, then, Einstein is in agreement with his critics, and there is no difficulty. These observers, at rest with respect to each other, constitute what is known as a "frame of reference." If there is another group of observers having a common velocity with respect to the former group, they will constitute another frame of reference.

Now the difficulty—and the only difficulty—occurs when we try to determine whether events which are simultaneous in a given system of reference are also simultaneous in a frame of reference endowed with motion with respect to the first.

Einstein maintains that they are not. I translate literally, from the original text,[1] the celebrated passage where he makes this declaration, a passage which we must keep constantly before us in order to follow this discussion, since it is at the bottom of all the present controversies.

Einstein begins by giving the definition of simultaneity which we mentioned above. If we were to know, for instance, whether two flashes at the points A and B on a railway are simultaneous "we measure the distance A B in a straight line along the railway and place at M, midway between, an observer provided with an apparatus (such as two mirrors inclined at 90°) which enables him to observe the two points

[1] *Uber die spezielle und die allgemeine Relativitätstheorie gemeinverständlich, von A. Einstein.* This famous work has been translated into most European languages.

A and B simultaneously. If the observer perceives the two flashes at the same instant, they are simultaneous."

So far, so good. Einstein then pursues his proof as follows, in a passage famous because of the floods of ink it has made to run :

"Until now we have confined our considerations to a certain frame of reference, viz. the railway. Let us now consider a very long train moving along the railway with a constant speed v, in the direction indicated by the arrow in Fig. 1. The travellers by

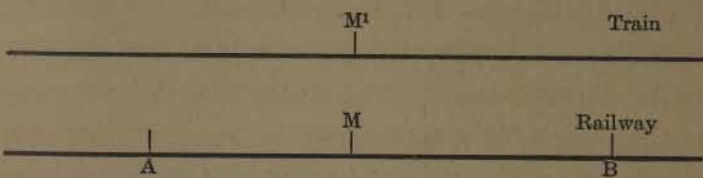

Fig. 1.

this train find it an advantage to regard the train itself as their final frame of reference. They refer all events to the train. Every event, therefore, which takes place along the line will also take place at a certain point on the train. Similarly, the definition of simultaneity with respect to the train is made in the same way as that with respect to the railway. But then the following question naturally presents itself : Are two events (such as the two flashes A and B which are simultaneous with respect to the railway) also simultaneous with respect to the train ? We shall now show that the reply to this question is in the negative.

"When we say that the flashes A and B are simultaneous with respect to the railway we mean this: the rays of light emitted by the points A and B meet in the middle M of the portion of railway AB. But the flashes at A and B are also events at the points A and B of the train. Let M[1] be the middle of the portion AB of the moving train. The point M[1] coincides with the point M at the moment (with respect to the railway) when the flashes are produced, but it is subsequently displaced along the diagram with the velocity v of the train, and towards the right. If an observer in the train at M[1] were not carried along with that speed, he would remain permanently at M, and in this case the luminous rays from the flashes A and B would reach him simultaneously, that is to say, these two rays would meet precisely in him.

"*But in reality (from the point of view of the railway) he moves to meet the luminous ray coming from B and flies before the luminous ray coming from A. This observer will therefore see the luminous ray from B sooner*[1] *than the ray coming from A. The observers who use the train as a system of reference must therefore*

[1] It goes without saying that this difference is extremely small for ordinary train speeds. It only becomes practically appreciable at enormous speeds. But what matters here, and in all that follows, is not the amount of the difference, but its existence.

come to the conclusion that the flash B occurs earlier than the flash A.

"We thus arrive at this important result: events which are simultaneous with respect to the railway are not simultaneous with respect to the train and vice versa (relativity of simultaneity). Every frame of reference (system of co-ordinates) has its own time. No indication of time has therefore any meaning unless we specify the system of reference."

Such is the memorable demonstration of the "relativity of simultaneity" given by Einstein, concerning which M. Bergson, M. Maritain, and others of lesser celebrity have disputed, and which we shall now discuss in the hope—whether too daring a hope the reader will judge—of introducing the necessary clearness which will bring about a general agreement. In the subtile and beautiful pages which he has devoted to the deeper criticism of this Einsteinian demonstration, M. Bergson, for the sake of greater clearness, has called the observers on the line and on the train Peter and Paul respectively. In order to enable us to follow the discussion more clearly, I shall call the observer on the train Thomas and the observer on the line Lewis, thus indicating their position by their initial letters.

The reasoning of M. Bergson and M. Maritain may be summarised as follows:

What does M. Einstein's demonstration really prove? It proves that Lewis, the observer on the railway line, who sees the two flashes simultaneously, also sees that these two flashes cannot be simultaneous for Thomas, the observer in the train. The reason for Lewis's judgment is that he sees Thomas run in front of one of the rays and run to meet the other. In Lewis's opinion, therefore, the two flashes cannot be simultaneous for the eyes of Thomas. This is beyond a doubt. But, as MM. Bergson and Maritain justly observe, this judgment, opinion, or conviction of Lewis is peculiar to Lewis. It only proves this, and nothing else: *From Lewis's point of view*, what is simultaneous to himself is not simultaneous for an observer who, like Thomas, is undergoing displacement with respect to himself, Lewis.

What Einstein's reasoning establishes, and the only thing it does establish, is that the observer on the line, Lewis, necessarily judges that events simultaneous with respect to the railway line are not simultaneous as judged from a moving train. But this reasoning does not suffice to prove that these events are not *really* simultaneous for Thomas, and that in reality Thomas does not perceive them simultaneously. To prove this, it would be necessary for Lewis to know about the perceptions of Thomas and the conclusions he draws from them. But nothing in the argument leads us to suppose that he does. He only knows his own perceptions and his own judgments. In a word, to use M. Maritain's unassailable terms, to conclude from Einstein's reasoning that simultaneity is really and intrinsically relative, and not only from Lewis's unilateral point of view, is *to confound the perceptions of Thomas with Lewis's judgment concerning the perceptions of Thomas.* It is "a sort of intellectual optical illusion," as M. Maritain says, or what M. Bergson calls "a mirage effect."

The latter has very rightly concluded from Einstein's above proof that if "simultaneity with respect to the railway is not simultaneity with respect to the train" it is on the condition that a system of physics is constructed from the point of view of the train. But such a system of physics is one-sided, and could not in any case claim to give us an image of reality which is objective and independent of the conditions of observation and the particular observer. In short, such a system of physics will be, or would be, an arbitrary representation of the Universe.

The various conclusions drawn by M. Bergson and M. Maritain, each in his own way, are of two sorts. Some of them are purely speculative, and others are purely scientific and positive. The former, in which both philosophers, though otherwise much in opposition to each other, agree no less than in their refutation of Einstein, amount to the admission of an absolute time. "Intuitive simultaneity," as defined by M. Bergson in his own fluid and finely shaded style, is a conception which escapes all experimental criteria. Similarly, M. Maritain lays down the principle that "it is impossible to build up a sane philosophy of nature unless we restore, not against unrelated physico-mathematical sciences, but against the physico-mathematical physics founded by Descartes, the reality of absolute motion." Elsewhere, M. Maritain declares that "the relativity of real time is an absurdity" and absolutely denies the possibility and the right "of physicists to undertake, with astonishing presumption, the revision of the common motions of space, time, and simultaneity whose elucidation appertains to a superior science which entirely exceeds their competence." That superior science, M. Maritain declares without more ado, is metaphysics. Thus the speculative ideas, concordant in themselves, arrived at by MM. Bergson and Maritain, "lie entirely beyond" the domain of physics. They do so because they are founded on psychological introspection and intuition on the one hand, and upon metaphysics on the other hand. This amounts to saying that by definition and *a priori* these ideas are unaffected by, and superior to, all physical verification, and all experiments relative to the external world which are the proper domain of the physicist.

It follows that these speculative ideas could not have received any confirmation from the refutation inflicted by these illustrious authors upon Einstein's demonstration. Nor, indeed, would they have been shaken if they had pronounced that demonstration to be convincing and unassailable.

We shall, therefore, not go any farther into these general ideas, however interesting they may be. Our object here is to concern ourselves not with metaphysical time but with time as observed, defined, and measured in the sensible universe, in the external world, and which is, or at least should be, the time of the physicist.

From this point of view nothing is more remarkable than the conclusions drawn by M. Bergson and subsequently by M. Maritain from their refutation of the Einsteinian demonstration of the "relativity of simultaneity." These conclusions are clear and very simple. They can be summarised as follows: "The relativity of simultaneity as proved by Einstein is a fictitious simultaneity" and not a real simultaneity. Indeed, "what we call real is that which we perceive, or are able to perceive" (Bergson) and the observer on the rails, according to Einstein's own proof, does not know what the observer in the train perceives. Einstein's scientific and unilateral relativity is only that of a particular observer who knows nothing about the simultaneity of other observers. It therefore has no connection with "real simultaneity." To confound the two constitutes a fallacy, a misunderstanding, and an "illusion." Physics constructed on this simultaneity of a particular observer cannot be an exact and intrinsic image of reality. Though perfectly coherent from the mathematical point of view, Einstein's theory, as far as it is founded on the demonstration discussed above, can only give what Bergson calls a "phantasmic image" of the real Universe. As regards M. Maritain, his conclusion, though identical with Bergson's, is expressed in much more open and categorical terms: The conclusion drawn from Einstein's demonstration concerning the relativity of simultaneity "is nothing but false coin." The example of Einstein's theory "shows how a physico-mathematical theory, in itself irreproachable and of immense scientific interest (whatever may be its absolute value) can, as soon as it leaves the domain of purely mathematical symbols, find itself formulated in an incorrect manner, and may thus figure as a pseudo-metaphysical grade which, though put forward in simplicity and good faith, yet amounts to a poor intellectual buffoonery." In short "the relative simultaneities and dislocated times used in this (Einstein's) theory are not the real simultaneity nor real time."

I believe I am safe in saying that Einstein and the relativists will be inclined to accept this severe condemnation rather than the "attenuating circumstances" allowed by those who pronounce it. If there is an opinion against which Einstein has always vigorously protested, notably, it will be remembered, in the debates at the Collège de France, it is the view which attributes to his theory a purely formal and mathematical value. On the contrary, Einstein and with him that most eminent of French relativists, Paul Langevin, has always insisted on the fact that his theory claims to express physical facts, the sensible phenomena of the external world, and that the "time" with which it deals is everybody's time, the time measured by clocks, and counted in days and years.

If, therefore, Einstein's theory is reduced to nothing but a mathematical construction, however coherent, to nothing but a representation of the external world which is arbitrary and inadequate for reality, then Einstein and all relativists will agree without hesitation that the theory has failed and that its condemnation allows of no attenuating circumstances.

But there have been condemnations without attenuating circumstances which yet were fit cases for appeal. Is this one of them? That is what we must discuss now.

If Einstein's famous demonstration is taken literally—and unfortunately we cannot take it otherwise — it is certain that the criticisms and refutations by his opponents seem justified.

Yet there are two singular matters which occur to us at the outset. It is certain that the theory of relativity, which, according to these writers, rests entirely on the conclusion of this fallacious demonstration, is something very different from a purely formal mathematical framework. For, like the classical theories, it acounts for all the mechanical phenomena already known. That, of course, applies to all new theories, since they must avoid contradicting known facts for fear of being rejected there and then. But relativity does more than that: it enables us to foresee new phenomena hitherto unsuspected, which could not be predicted from classical theories. These new facts announced by Einstein have been effectively verified, notably the most important of them, viz. the curvature of light under the influence of gravitation. It seems very extraordinary that a purely formal theory based upon an unproved or inexactly demonstrated principle—the relativity of simultaneity—should be able to predict unsuspected facts subsequently verified by observation. It is true that false premises can lead to correct conclusions. That has happened, but it does not happen often. All this is sufficient to make us pause and refrain from too categorical judgments.

The second singular point of this debate has been brought forward by both M. Bergson and M. Maritain. It is that Einstein's incriminated demonstration really seems to be *anti-relativist.*

M. Bergson, for his part, remarks (*loc cit. passim*) : "Taking Einstein's demonstration literally (and it is unfortunately impossible to take it otherwise) we are driven to the conclusion that if simultaneity is *really* relative it is because Lewis judges, accordant to his own observations and without being able to consult Thomas, that that which he (Lewis) sees to be simultaneous is not seen as simultaneous by Thomas. In a word, this demonstration amounts to putting forward Lewis's one-sided point of view as that which alone recognises absolute reality. It amounts to a declaration that Lewis's frame of reference is a privileged system, a system which sees phenomena as they really are." Now the basis and root principle of Einstein's theory is that there is no privileged system and that the points of view of all systems enjoy absolute reciprocity, the observations and perceptions of each being of the same value. M. Bergson has very clearly grasped this contradiction between Einstein's criticised demonstration and the principles laid down by him. That demonstration would thus be anti-Einstein. Carrying the logical sequence of his remarks a stage farther, M. Bergson even concludes, on account of the reciprocity of the various frames of reference fundamentally implied by the theory, that what is simultaneous for Lewis must be the same for Thomas, and hence that simultaneity is not relative but absolute. Thus, according to M. Bergson, " Einstein's theses not only do not contradict, but they even confirm the natural belief of mankind in a unique and universal time " (*loc. cit.*, p. vi). And his conclusion is formulated later (*loc. cit.*, p. 165) as follows : " The suppression of the privileged system is the very essence of the theory of relativity. Thus this theory, so far from excluding this hypothesis of a unique time, establishes it and makes it more intelligible." However paradoxical it may seem, and contrary to what Einstein concluded from the same premises, this rigorous conclusion of M. Bergson would be perfectly unassailable if—but we must not anticipate.

M. Maritain, from another angle, also sees something anti-relativistic in the much-discussed Einstein demonstration. Having analysed this demonstration, M. Maritain proceeds (*loc. cit.*, pp. 65–67) : " What does it mean except that you compound the speed of light and that of the observer according to the ordinary rules of the composition of velocities ? To say, for instance, that since light travels at 300,000 kilometres per second he receives the image of B before that of A, *because he himself moves towards B*[1] at the rate of 100,000 kilometres per second,

[1] Author's italics.

means that the velocity of light from B with respect to him is 400,000 kilometres per second, while the velocity of light from A is 200,000 kilometres per second with respect to him." There is a contradiction between this statement implied by Einstein's reasoning and the "principle of the invariance of the velocity of light" which he presupposes, either as a free convention or as a so-called demonstrated conclusion.

Thus it would appear clearly that Einstein's incriminated proof, taken literally, is anti-relativist at the outset, and that it contains an internal contradiction between its premises and its conclusions.

That is surely a singular riddle. To solve it we must summarise the points we have arrived at. They are, as everyone will agree, as follows:

(1) The theory of relativity is entirely founded on the relativity of simultaneity.

(2) The demonstration of this relativity of simultaneity given in Einstein's well-known text and attacked by M. Bergson and M. Maritain does not suffice to prove that simultaneity is really relative. This demonstration would, therefore, be without force and any conclusions from it would be invalid. Bergson's and Maritain's criticisms seem irrefutable and one might challenge every mathematician and physicist in the world to refute them.

(3) If Einstein's theory is really founded on this

single demonstration of the relative character of simultaneity, that theory does not hold good.

The third of these points is the essential one, and the only one of any importance. Yet it seems to have passed unnoticed. We shall examine it now.

Was it on the above well-known demonstration, so justly attacked by Bergson and Maritain, that Einstein really originally founded his theory of restricted relativity? By no means. This is evident if we refer to the essential original memoir which was the foundation of the theory and which was published in the *Annalen der Physik*, vol. 17, in 1905, many years before the popular little work from which the disputed passage is taken.

In this initial memoir, the relativity of simultaneity follows rigorously from Lorentz's celebrated equations of transformation on the one hand, and from the principle of the constancy of the velocity of light on the other. The Lorentz equations express and reconcile the apparently contradictory facts made evident by electromagnetic experiments and by classical mechanics. On the other hand, the constancy of the velocity of light in all directions and for all observers is a principle laid down by Einstein, and is in accordance with all experimental results. This principle, and the Lorentz equations, therefore, express experimental and observational facts. Now by combining these principles and these observations, Einstein directly deduced the relativity of simultaneity. These equations thus necessarily imply the relativity of simultaneity and the relativity of time.

The demonstration of the latter results, therefore, from a rigorous and irrefutable calculation.

How did it happen that Einstein later substituted for this incontestable demonstration of 1905 the demonstration first criticised by M. Bergson? It is because the latter was intended for a small book written to make the theory popularly intelligible (*gemeinverständlich*). The idea was to substitute for a calculation and a mathematical demonstration a demonstration made with "nothing but words," and without formulæ. It was a matter enabling a non-mathematical public to understand and get hold of a subtile and difficult matter.

In this particular enterprise Einstein has failed, though, as we shall see, only because his demonstration was incomplete, and therefore insufficient. His popular demonstration is open to M. Bergson's just criticisms. It does not suffice to prove what it claims to prove. This brings home to us the difficulties sometimes encountered in trying to popularise ideas involving a mathematical proof.

But the conclusion is obvious. Bergson's and Maritain's criticisms are quite justified when applied to Einstein as a populariser, and they would be correct in asserting that he had popularised badly. But the criticisms fall to the ground as soon as they attack the theory itself. Einstein has given a defective and deformed idea, an incorrect or, rather, *incomplete* version of his proof by calculation. Only this version is open to criticism, and has been criticised, not the theory itself.

This is, I believe, the explanation of the misunderstanding or fallacy which separates Bergson and Maritain from Einstein. We cannot doubt that on further information these eminent men will agree with him on the point at issue and will, with the lofty outlook worthy of their great minds, recognise that though their objections were well founded they had no bearing on the theory of relativity, but only on a defective rendering which slipped from Einstein's pen.

But, somebody might say, if it is really impossible to give without calculation and without equations an exact proof of the Einsteinian relativity of time, how shall the uninitiated be got to accept it? Time and the simultaneity of events are things which come under everybody's observation and which everybody can understand. How can you expect the assent of all to a quite unusual set of ideas on the nature of these things unless you furnish a demonstration which is also intelligible to everybody? Does it not demand a sort of "act of faith" irreconcilable with liberty of discussion in scientific matters to say "it is so because calculation proves it, because *magister ipse dixit*"?

Einstein understood the justice of this point of view so well that he attempted a demonstration without algebra in the celebrated passage which has raised so much controversy. We have seen that he failed. But I now propose to show that by changing very little in this passage we can give a demonstration in words alone of the relativity of simultaneity which may be understood by all and which will not be liable to any objection.

In making this attempt I do not, of course, wish to put myself above Einstein. In what follows I do not make the absurd claim of bringing any contribution, however small, to the scientific work of that powerful genius. It is only a question of popularising, expressing in words alone, and interpreting in ordinary language, without any addition, a particular and indeed essential point. This is how I believe one may demonstrate the relative character of time while appealing to nothing but facts and common sense.

Let us, like Einstein, take a straight railway line and a train of indefinite length consisting of a single corridor carriage passing in the direction of the arrow with a speed v. At a point M of the railway line an observer, Lewis, is stationed, while another observer, Thomas, sits on the train at the point M′.

Lewis, like Einstein's observer, is provided with an apparatus (such as two mirrors inclined at 90°) which enables him to observe at a glance two points A and B situated to his right and to his left respectively, and equidistant from M. He is also provided with an apparatus which enables him to produce in A and B respectively electric sparks which he will see at the same instant. Such an arrangement might be a wireless transmitter, which, as we know, transmits

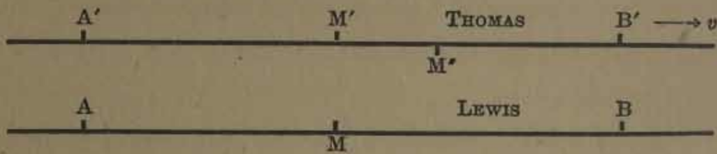

FIG. 2.—M′, A′ and B′ are the positions occupied by Thomas and the two marks on the train respectively, from Lewis's point of view, at the moment when the sparks pass.

with the speed of light. At a given moment, Lewis will produce an instantaneous transmission. This will be propagated to the right and left. At A and B there are fine metallic points which almost touch the train, and when the wireless impulse reaches these, a spark passes between each point and the train. The spark at A will make a mark on the train at A′. The spark at B will make a mark at B′, which touches B. The spark AA′ and the spark BB′ will be seen simultaneously by Lewis. This follows from the definition of simultaneity. It also follows from Michelson's experiment and all similar experiments, which have proved that when two luminous waves coming from the same centre return to it from two equidistant points they return exactly at the same time, whatever may be the speed of the system as a whole.

Lewis's arrangement is, indeed, a form of Michelson's experiment. The two sparks AA′ and BB′ will be seen by Lewis at the same instant.

Will they also be seen simultaneously by an observer, Thomas, sitting on the train at the point M′, midway between A′ and B′?

I say No.

If light had an infinite speed, if its propagation were instantaneous, as implied by the classical notion of absolute time, it is certain that the sparks AA′ and BB′ would be seen by Thomas at the moment they pass and that moment A would still be in contact with A′, B with B′, and consequently M with M′, that is, Thomas with Lewis. But in reality, as we know, light takes a certain time to arrive at the observers from the sparks AA′ and BB′. While the light is on the way, Thomas is carried by the train away from Lewis at M towards the right. At the moment when the light rays from the two sparks meet at Lewis's station, Thomas is at some point between M′ and B′, say at M″. Since the two rays meet at M (and they can only meet in one point) it follows that the ray from the spark AA′ arrives at that crossing *before* it arrives at M″, while the ray from the spark BB′ reaches that crossing point *after* passing M″.[1]

Thus, while Lewis sees the two sparks at the same time, Thomas, though originally midway between the two sparks,[2] sees the spark BB′ before he sees the spark AA′. Q.E.D.

It will be noticed that in this demonstration there is no longer any question of the movement of either one or the other of the two observers with respect to the light rays, nor of the judgment of either observer concerning the perceptions of the other. It therefore escapes Bergson's objections.

We thus arrive without difficulty at the "important result" (*wichtiges Ergebnis*) announced by Einstein. *Events which are simultaneous and contemporary with respect to the railway line are no longer so with respect to the train, and vice versa.*

This *vice versa* requires proof. Nothing is easier. It suffices to assume that Thomas has the same apparatus which we have given to Lewis, and that he can with their aid produce two sparks seen simultaneously by himself (Thomas).

[1] If the train travels in the opposite direction the reverse would happen, so that the order of succession of two different events might be reversed for different observers. M. Langevin has clearly shown the limits of such reversal, without offending our sense of cause and effect.

[2] Each observer naturally and rightly considers the sparking points as belonging to his own system.

If we then consider the train to be at rest and the rails as moving to the left (which is permissible not only in Einstein's relativity, but also in classical mechanics) and repeat point for point the above reasoning we find that sparks seen simultaneously by Thomas are no longer simultaneous for Lewis.

We can also invert the preceding demonstration and prove, as we shall see, that if two events close together are not simultaneous for a given observer they are in general[1] simultaneous for a certain other observer in motion with respect to the former.[2]

Let us suppose that the observer Lewis stationed at M on the permanent way produces with his apparatus first a spark at the point A and then a spark at the point B, B and A being equidistant from M. These two sparks make, as before, marks at A′ and B′, the points where the spark passed between the train and the metallic sparking points.

Lewis will by definition see the spark AA′ before he sees the spark BB′. Hence the luminous rays from AA′ will encounter the ray from BB′ at a certain point situated to the right of M, as for instance, at

[1] This possibility is realised whenever the distance in space between the events considered is greater than the distance covered by light during the time interval between them (see Langevin, *Bulletin de la Société de Philosophie*, January 1912.

[2] This is obvious, as Langevin says, since the order of events can be reversed in two different systems and therefore there must be an intermediate system for which they are simultaneous. But we consider that the direct proof as given above is of interest.

m. Let us suppose that a third observer, Lawrence, is stationed at *m*. He will then see the two flashes at the same time, but he will know that the two flashes are not really simultaneous since they originate at points at unequal distances from himself.

Let us now consider an observer, Thomas, sitting on the train at M′, a point which arrives at *m* at the instant when the rays from the two flashes meet there. This instant is quite clearly defined for all observers, both on the line and on the train. It is

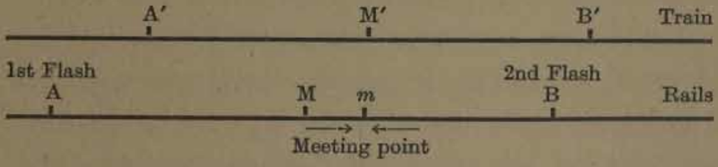

FIG. 3.—The figure represents the positions of the train observer Thomas and the marks A′ and B′ on the train at the moment when Thomas reaches the point *m*.

in fact the instant when Thomas and Lawrence meet and can, if quick enough, shake hands.

At that instant, where are the two points A′ and B′ of the train where the sparks left their marks? Lawrence knows that the first flash AA′ was produced earlier than the second, BB′. Therefore he knows and can prove that the point A′ of the train has been longer travelling to the right than the point B′ has been. A′ and B′ having the same speed, which is that of the train, it follows that if at the moment when Thomas and Lawrence meet, B′ is found at the point shown in the diagram, A′ will be found in a different place A′, such that the distance BB′ is less than AA′.

Now the observer Thomas, sitting in the train at M′, perceives the two flashes AA′ and BB′ simultaneously since he finds himself at *m* at the very instant when the two luminous rays from the flashes meet there. In order that the two flashes should appear simultaneous to him, it suffices that M′ be midway between A′ and B′, which is realised in the diagram. This necessary and sufficient condition is realised when the time (measured either by the observers on the line or on the train) taken by the train to cover the distance BB′ is equal to the time taken by light to cover the distance B*m*, while the time taken by the train to cover the distance AA′ is equal to that taken by light to cover the distance A*m*. This condition is, indeed, expressed mathematically by a simple and easily realised relation between the speed of the train, the speed of light, and the distance M*m*.

It follows that two events not simultaneous for the railway can be simultaneous for another system of reference. Q.E.D.

It will be clear from the preceding demonstrations that the time interval between two given events, if zero for one frame of reference, differs from zero for others, though the interval is defined and measured in an identical manner by the observers interested.

That is the relativity of time, and of real time, measured by means of identical clocks, which the observers may have compared and set before setting themselves in relative motion.

This relativity follows clearly from the generally agreed definition of simultaneity on the one hand, and from the experimental fact that the propagation of light is isotropic and its speed always the same, on the other hand.

In Einstein's relativity of time there is nothing arbitrary, purely formal, or fallacious. There is nothing but what is based upon experimental facts and upon them alone.

The above demonstrations are, I believe, completely free from the objection brought by Einstein's opponents that they are one-sided and assume the existence of a privileged system, since we have shown that they can be exchanged by placing ourselves on the point of view of one or other of the moving systems without affecting the result.

But it might be objected that there is one privileged system among various frames of reference in relative motion, viz. the system for which, and for which alone, two given events are simultaneous. That is true. That system possesses the privilege of being the only one for which such simultaneity exists.

But if we consider another pair of events, it will be in general some other system which, and which alone, will have the privilege of considering them simultaneous. In short, every frame of reference enjoys, to the exclusion of others, the privilege of judging such and such a pair of events to be simultaneous. If all systems are equally privileged in this respect it amounts to saying that none is specially privileged, but that they are all equivalent, as is demanded by the principle of relativity in its widest sense.

All the confusions, fallacies, and ambiguities hitherto arising are simply due to a misunderstanding and misinterpretation of this one fact: *Two rays of light coming from different events meet in one point, and one point only.* Their encounter constitutes a unique and well-marked event. If an observer happens to be at that point at the moment of the encounter, and if he is at the same distance from both sources of light, his system of reference will have the fortuitous privilege of being the only one for which the two events are simultaneous.

To put it briefly, the relativity of simultaneity is absolute, and that alone is absolute. To paraphrase a celebrated saying: "All is relative, and that fact alone is absolute." There is nothing here which contradicts relativity in its widest sense, but on the contrary. Unless everything is relative, even simultaneity, there will be no more relativity. After all, there is no contradiction between this sort of relativity and the physically absolute character of the relativity of simultaneity perceived by all observers.

One more remark. The various frames of reference in relative motion used for judging of the interval between two events will give different results, even if provided with identical measuring instruments. The system for which the interval is zero will indicate that the events are simultaneous. It would give the same result if instead of light any other radiation were employed, even though it had a greater speed, provided that it had an "isotropic" propagation. In this case, the interval indicated in other systems would be different. In other words, if in order to synchronise clocks and observe the phenomena we were to employ other physical agents of different speeds, but propagated isotropically like light, the time intervals between two phenomena would depend on the physical agent in all systems of reference except one. That one system would be that for which the two events were simultaneous, and the interval between them zero. Such an advantage occurs in all the "null methods" used by physicists.

At the close of this study I may perhaps search among the qualified authors who have attempted to expound the theory of relativity for those who have endeavoured, after Einstein himself, to demonstrate the relativity of time "with nothing but words." It seemed particularly interesting to find whether their demonstrations had escaped the difficulties and objections raised by Einstein's famous *gemeinverständlich* demonstration, which we have endeavoured to avoid above.

Here is the very interesting result :

Mr. Eddington, in a well-known book on the theory of relativity which has been translated into French, has not touched upon the demonstration of the relative character of simultaneity.

Neither has M. Émile Borel in his book *L'Espace et le Temps*.

M. Thirring has copied Einstein's "popular" demonstration and aggravated it. His text, therefore, raises the same difficulties as those we have already dealt with.

M. Jean Becquerel, in his *Exposé Élémentaire de la Théorie d'Einstein* tackles the point. But his demonstration simply amounts to establishing the fact that the relative character of simultaneity may be deduced by combining Lorentz's equations with the principle of the invariance of the velocity of light. It is true, but it is simply the demonstration given by Einstein in his original memoir of 1905. That demonstration had already been reproduced by M. Becquerel in his chapters on the Principle of Relativity, which were, however, highly mathematical, without any attempt at popularisation and naturally found a place there. But the same demonstration was out of place in a so-called *elementary* exposition. One would have expected M. Becquerel not to prove by calculation as Einstein had done, but to endeavour to show "in words alone" what were the essential facts in the matter. That eminent relativist has, in fact, not tackled the difficulty, which might well have tempted him.

Such is not the case with M. P. Langevin, professor at the Collège de France. M. Langevin is indisputably the most eminent of French relativists. All those who have concerned themselves closely or even remotely with relativity owe much to his magnificent teaching. Not only has M. Langevin made known this scientific revolution in his masterly lectures, not only has he contributed more than others to establishing its place in the world, but he has even taken part in building up the theory by his personal work, particularly by his remarkable discoveries concerning the inertia of energy.

Not content with the mathematical proof, which is incontestable and uncontested, he has endeavoured to make the relativity of simultaneity comprehensible without calculation. With this intention, M. Langevin, like Einstein, has worked out a reasoning free from formulæ. He gives the following demonstration,[1] which we shall first quote *verbatim* before discussing it. M. Langevin designates by O and O′ two systems of reference in relative motion and carrying observers. He proceeds :

"In order to understand how the Principle of Relativity, in maintaining that light is propagated with the same speed in every direction for all groups of observers in a uniform movement of translation, requires a reconstruction of the idea of simultaneity and only leaves it a relative sense, let us take the following example :

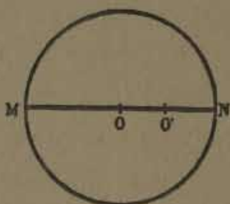

FIG. 4.

"Let us imagine (Fig. 4) that a spark flashes in an apparatus at rest with respect to the observers in O′, and let us take this event as a starting point in the two systems O and O′. For the O observers, the wave-front emitted by the spark will, at the end of a second, be a spherical surface having a radius of 300,000 kilometres, described about the point where the apparatus was situated at the moment of emission. By virtue of its movement, that apparatus will, after

[1] Langevin, *La Physique depuis Vingt Ans*, Paris, Doin, 1923.

one second, have arrived at a point O′ situated at a distance OO′, which we may call v, from the origin of the wave. If receiving devices are stationed at M and N, the arrivals of the wave-front at these two stations will be simultaneous for the two observers. For the O′ observers, with respect to whom the emitting apparatus is fixed, and for whom light is also propagated with the same speed in all directions, light will require less time to arrive at N than it requires to reach M, so that the arrivals which are simultaneous for the O observers are no longer so for the O′ observers."

Let us examine M. Langevin's reasoning. For him, O and O′, as shown by his text and the context, represent respectively the points where the emission of the spark takes place as far as the observers of the two systems are concerned. In other words, at the end of a second the observers of the system O think that the wave-front of the spark comes from a point fixed with respect to themselves and situated at O, while the O′ observers, on the other hand, think that it comes from a different point, O′, fixed with respect to themselves.

Two receiving devices are situated at M and N respectively. The events considered by M. Langevin, whose simultaneity is to be decided, are the respective arrivals of the wave-front at the points M and N. These arrivals might be indicated, say, by two explosions. Let us call these events Explosion M and Explosion N respectively. It is clear that these explosions will be seen simultaneously by an observer in the O system who is equidistant from M and N, and he will conclude that they are simultaneous. It is also clear that the two explosions will not be seen simultaneously by the observer in the O′ system since the observer at the moment of perception will be nearer N than M. But if the latter observer is to have a right to conclude that the flashes are not really simultaneous he must be equidistant from M and N at the moment of perception, which he is not. M. Langevin's demonstration is, therefore, insufficient to prove the relativity of simultaneity. To prove it, it would have been necessary to consider and compare the perceptions of the two observers in both systems who are equidistant from the two explosions when they perceive them. It is true that, when he presented this image, M. Langevin was addressing an audience of philosophers, whom he no doubt considered competent to complete the demonstration sketched by him. As it stands, it is not absolutely conclusive.

The celebrated physicist to whom we owe so many discoveries which will leave traces in our science for a long time, has too high a conception of truth to fail to understand the motives which lead me to say that his demonstration is not perfect. Also, this criticism is not addressed to the *savant* whose magnificent work is beyond criticism, but solely to the populariser. That such eminent people, that a Langevin as well as an Einstein, did not completely succeed in making the Einsteinian relativity of time comprehensible and tangible " with words alone " may lead some Philistine to give himself contemptuous airs. People who think will, however, only find a proof of the difficulty of popularising certain notions whose purely scientific demonstration is uncontested, thanks to the expressive and demonstrative force of calculation.

To sum up, I think I have in this chapter established the following points :

(1) The defects of reasoning pointed out by some of Einstein's critics in a passage of his popularisation essay (and there alone) and the objections deduced therefrom do not shake the theory of relativity.

(2) By making a small change in Einstein's argument it is possible to demonstrate without calculation, " with words alone," and by reasoning which is free from those objections, the Relativity of Time, the essential foundation of the theory.

CHAPTER VII

STRANGE CONSEQUENCES OF THE RELATIVITY OF TIME

The luminous pendulum and the dilatation of Time by speed—The Lorentz-Einstein contraction—Its demonstration by calculation—Comparison of lengths with metre-sticks and clocks—Demonstration of the contraction without formulæ—Newton as a relativist—Metaphysical possibility and physical reality—The moon and the retardation of the celestial clock—Conclusion.

It is already some time since Henri Poincaré pointed out the difficulty of knowing whether one of two events in the external world precedes another or occurs at the same time.

That difficulty does not occur in the case of psychological time, that intimate time so acutely and profoundly studied by M. Bergson, the only field of which is the closed area of our consciousness. I can define my meaning perfectly when I say that I think of one thing at one time and of another thing afterwards, or if I declare that of two things which I remember one has preceded the other. "The order in which we arrange the phenomena of consciousness," says Henri Poincaré, "has nothing arbitrary about it. It is imposed upon us and we cannot make any change in it."

The difficulty, or rather the difficulties, come in when we are to determine the order in which two events succeed each other when they take place outside ourselves and at different points in space. Poincaré had pointed out that time must be relative because "absolute time," though philosophically conceivable, is not physically measurable. In fact, "if all phenomena were slowed down, including our clocks, we could not discover the fact, whatever might be the law of retardation, always provided that it was the same for all sorts of phenomena and for all time-pieces." The measurement of time, or of the duration which separates two events, is closely linked with the question of knowing whether they are successive.

Poincaré had perceived, with his wonderful intuition, that it is very difficult to separate the quantitative problem of the measurement of time from the qualitative problem of simultaneity. But what Poincaré had not suspected, and what Einstein has established, is that simultaneity itself is relative and depends upon the speed of the observer. It is this stroke of genius which has solved all the difficulties so subtilely noted by Poincaré. We have seen how Einstein solved them by his uncontested definition of simultaneity, and by showing that the measurement of time and the synchronisation of our clocks are carried out by means of light signals, or, what amounts to the same thing, by means of electrical signals or

Hertzian waves. We now know very well what we mean when we say that two events of the external world are simultaneous. We also know, since our previous chapter, that these two events, simultaneous for us, are not simultaneous for other observers in motion with respect to ourselves.

This leads to various consequences, some of which may appear very strange at first sight. The first, and not the most singular, is that phenomena and events occurring in a system in motion relative to ourselves seem to succeed each other more slowly than they would if that system were at rest.

This results immediately from the Lorentz formulæ combined with the invariance of the speed of light. Einstein, in one of his famous lectures at the Collège de France, showed in a very simple manner how this astonishing result can be made clear without formulæ.

Let us repeat that light plays an essential part in the regulation of chronometers and the very definition of physical time, of measured time. The duration of a second, in the last analysis, could not be better defined than by the time necessary for light to cover the space of about 300,000 kilometres, which represents the constant speed of light. Let us, then, suppose that the unit of time is defined as the time taken by a ray of light to traverse the space between two parallel mirrors between which the ray is reflected in both directions. This going and coming of a ray between two mirrors is the type of periodical physical phenomena by which—better than by the coarse vibrations of the pendulum subject to a hundred perturbations—time is practically subdivided. This double journey will, for instance, define the 300-millionth of a second if the distance between the two mirrors is half a metre. That will be the value of the duration considered for an observer at rest with respect to both mirrors.

Now let us suppose that the system carrying the

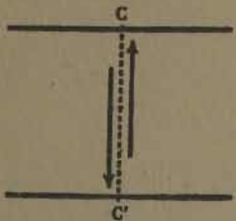

FIG. 5.—Case of mirrors at rest.

two mirrors passes by at a very great speed in a line parallel with the mirrors. I, who see it passing, notice that the ray which proceeds from the centre of the first mirror must, in order to reach the centre of the second mirror and return to the centre of the first, trace out a path doubly and slightly inclined to the normal on the mirrors, and thus inclined in the direction of translation. It follows that the path which to a man immovable with respect to the mirrors defines the unit of time will mean a longer unit to me. The duration of a second is longer for him than it is for me. In other words, the durations of all phenomena and all the happenings on a vehicle in very rapid motion will appear slowed down and prolonged to an immovable observer and vice versa. Q.E.D.

Einstein's demonstration involves the following consequences:

The succession of all kinds of events and in particular the interval which separates the birth and death of any creature, that is, its life, will appear to be

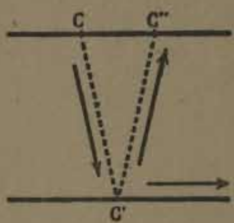

FIG. 5a.—Case of mirrors moving in the direction of the arrow with respect to the observer. The observer perceives that the ray of light starting from the point C of the upper mirror must, in order to reach the point C′ of the lower mirror, follow a slanting path since C′ is displaced towards the right during that passage. The return ray C′C″ must also slant since the point C has passed on to C″ during the passage out and back.

lengthened if that creature is displaced very rapidly with respect to the observer. A friend and I sit side by side and smoke a cigar which lasts five minutes. We will suppose that we light fresh cigars and propose to smoke them for another five minutes by our watches, which are perfect and identical. If, as soon as his cigar is lighted, my friend starts in an aeroplane and careers round me at a great speed, I shall see him throw away his cigar well after I have finished mine, though he believes, according to his watch, that he has smoked it for just five minutes.

To take another example: If that friend, at the moment of entering that fantastic aeroplane, takes a dose of poison at the same time as another person who stays with me, and if the doses taken are adjusted so as to kill the two men in one hour exactly, I shall see the man next to me die sooner than the man in the aeroplane. If the speed of the aeroplane is 160,000 miles per second I shall see the man next to me die in an hour, while the man in the aeroplane will only appear to die in two hours. On the other hand, the pilot of the aeroplane will see the two fatal events happening in the reverse order.

In order that these extraordinary appearances should become visible, we must assume unheard-of speeds, much beyond the present and possibly the future mechanical powers of the human race. But in this domain that which is *practically realisable* is of less interest than what *is*. And what is, is that the duration of events appears lengthened to an observer with respect to whom they are in rapid motion. That the scale of lengthening does not in most cases become observable to our coarse measuring instruments does not interfere with their reality provided Einstein's premises are well founded. And it has not yet been proved that they are faulty. What we may call the "expansion of time by speed" may therefore for the present be taken, not as some abstract mathematical mirage, but as the expression of a reality.

In a word, quick movement means longer duration for others, though not for one's self. It also means an apparently longer duration of others. This is an unexpected extension of the classical adage: Immobility is Death.

We now come to what is perhaps the most surprising consequence of the relative character of simultaneity. I refer to the contraction of lengths by speed, that is, of the fact that, if the theory of relativity is true, the apparent dimensions of objects diminish when they are in movement with respect to the observer.

I have shown elsewhere (*Einstein et l'Univers*) that we have been led to that singular conception by various recent results of physics and notably by those of Michelson's famous experiment.

In that experiment, it will be remembered, an attempt was made to make the Earth's motion with respect to an immovable ether perceptible. It was expected—if the Earth really moved and revolved in an immovable ether—to see the path of the luminous rays utilised in the experiment lengthened. But no such lengthening was observed.

It was then that Lorentz proposed to explain this negative result by supposing that the supports of the apparatus with which Michelson's experiment was made, and hence also the distance between the mirrors between which the rays passed to and fro, had contracted, owing to their speed through the ether, and had contracted by the exact amount by which the path of the rays had been lengthened. Thus there was exact compensation.

I have shown elsewhere the unlikelihood involved in this application of the negative result of Michelson's experiment. I have also explained how Einstein had made the "Lorentz contraction" comprehensible and evident by simply combining the Lorentz equations which express it with the principle that light has a constant speed in all directions for all observers. I need not return to this argument here.

I only propose to show that one can, after all, give a simple and informal image which renders the Einsteinian contraction of lengths by speed tangible and sensitive. We need only use what we have established in the preceding chapter.

Certain *savants*, and these among the best, have stated that it is impossible *a priori* to prove that speed contracts objects except by mathematics. This contraction, they say, results solely from comparisons made by the observers in motion and the other observers of the times marked by their respective clocks and the measurements made with the metre-sticks they use.

This method of proving the "Lorentz contraction" is a correct one. It results immediately from calculation on combining the famous equations of Lorentz with the principle of the isotropic propagation of light. But it requires the complicated use of measuring sticks and clocks.

But is there no other way, no way appealing to our senses, of showing this famous contraction? We shall see that some such way can be found.

Let us point out at once that there is generally no need for yard-measures and clocks in comparing the apparent dimensions of two objects. Primitive man had observed that the apparent diameters of sun and moon were nearly the same, and greater than those of the stars and planets. For this they required neither foot-rules nor chronometers.

The possibility of comparing the apparent dimensions of two objects and of judging whether one is larger than another is anterior and exterior to the invention of instruments of precision. On exhibiting at a distance two scales side by side, one of them much longer than another, one does not need a metre-stick or a clock in order to judge which is the longer.

Let there be an observer comparing two objects which have the same dimensions when at rest. Let them first be placed at the same distance, and then let one of them be endowed with a great speed. If the Einstein contraction of lengths by speed really exists, that observer must necessarily judge, on seeing them pass by each other, that the moving object is smaller than the object at rest, and for this he will need no physical apparatus. We shall now show that this is indeed the case.

Let us recall, first of all, an important and incontestable point: The apparent size of an object, the apparent length of a ruler, and the like, at a certain

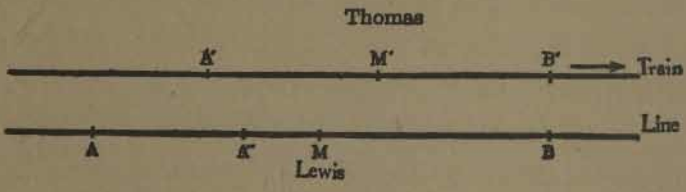

FIG. 6.

distance, is proportioned to the distance between the luminous points on our retina due to rays of light simultaneously arriving from the two ends of the object. "The length of a ruler," as Langevin truly says, "is defined by the distance in space between the two simultaneous positions—simultaneous for the observer—of the two ends of the ruler."

Now let us consider, as before, a railway line on which a train is moving. Let Lewis be an observer stationed on the line at M. Let us suppose that Lewis has planted two pegs at points A and B on the line, and that he is midway between them. The distances are so chosen that each car of the train fits exactly between the two pegs. This means that for Lewis the length of all the cars is AB. Let us also consider an observer, Thomas, seated in the middle of one of the cars, and let B′ and A′ be the front and tail of the car respectively. The instants when B′ passes the peg B and A′ passes the peg A are completely defined for both Lewis and Thomas. They might be, for instance, the moments when flags fixed on the two ends of the car brush the pegs A and B. The events thus constituted might be called BB′ and AA′ respectively.

Now I maintain that for Thomas the distance between the two pegs is less than the length of his car.

Let us consider the moment when for both Lewis and Thomas the front B′ of the car coincides with the peg B. If the propagation of light were instantaneous, Lewis would see Thomas pass by at M at the moment when the two ends of the car coincided with the pegs. But the propagation is not instantaneous. While the rays of light from AA′ and BB′ approach Lewis and eventually meet him (Fig. 6), Thomas is carried along by the train to the right. When he perceives the coincidence of B and B′ he is himself at M′. He therefore sees B′ coincide with B earlier than he sees the tail of his car A′ coincide with the peg A.

Thus when Thomas sees the front of his car coincide with the peg B he also sees that the tail of his car A′ has not yet arrived at the peg A. Thomas locates the peg A at A″ by means of the tail A′ of his car at the moment when the front of his car passes B. In other words, Thomas sees the front B′ of his car coinciding with the peg B and at the same time the tail A′ of his car beyond the other peg. For Thomas, therefore, the car, of length A′ B′ is longer than the apparent distance A″B of the two pegs he sees rushing past him. Q.E.D.

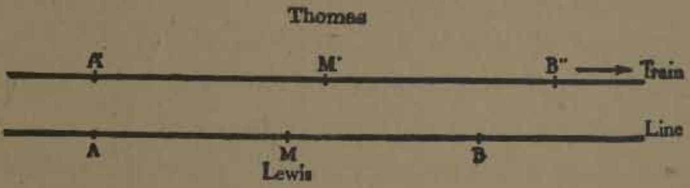

FIG. 7.

We obtain the same result if we consider (Fig. 7), not the moment when Thomas sees the front B′ of his car coinciding with the peg B, but the moment when he sees the tail A′ of his car coinciding with the peg A. This moment comes, as we have seen, after the former. It follows that when he sees the tail of his car coinciding with the peg A, Thomas sees at the same time that the front of the car has already passed the peg B and is, for example, at B″. Hence for him his car is longer than the distance AB, whereas Lewis sees the distance between to be the same as the length of the car.

We arrive at the same result for the case when Thomas perceives the distance AB between the pegs to be the same as the length of his car. In this case, by the same reasoning as before, it is easy to show that Lewis sees the car shorter than the distance AB.

Thus we find the contraction of lengths by speed demonstrated and made perceptible without measuring rods or chronometers.

This contraction will, of course, not be perceptible except at speeds vastly in excess of those of our habitual vehicles, and by observers with eyes capable of receiving instantaneous impressions. But here again it is not the magnitude of the effects which matters, but their existence.

Thus the relativity of Time, and the concomitant relativity of Space, are laid upon new bases, which are experimental and not merely ideological.

One may, of course, in the free exercise of metaphysical speculation, still believe that there is outside us and outside perceptible and measurable things an Absolute Time which, external and indifferent to contingencies, rolls its waters outside the sensible universe and irrigates no observable reality.

Newton believed in absolute time. "Absolute time," he wrote, "true mathematical time, unrelated to anything external, flows uniformly and is called duration." In writing this, Newton had the metaphysical notion of absolute time, since he considers it "unrelated to anything external." He then proceeds: "Relative, apparent, or common time is that sensible and external measure of any equal or unequal portion of duration in a state of motion, such as the measures of hours, days, months, etc."

And as if seized with a novel doubt, the great Newton wrote: "It is quite possible that there is no perfectly equable movement which can serve as an exact measure of time, for all movement may be accelerated or retarded." Is that not a glimpse of Relativity? Yet Newton added: "But absolute time must always flow at the same rate." In saying this he forgot his great principle: *Hypothesis non fingo.*

That absolute time is a conceivable entity there can be no doubt. But, as Mach pointed out, the *representability* of absolute time must not be confounded with its *recognisability*. In other words, the possibility of a thing must be distinguished from its reality. The former concerns metaphysics, while the latter belongs to physics, and is the only one which has any significance in science.

Curie proved that external circumstances such as temperature and pressure exercise no perceptible influence upon the speed of transformation of radium. The coefficient of disintegration is remarkably constant and Curie proposed to use it for the absolute measurement of time. But it is now clear that this coefficient would not really measure anything but a relative time, by a method which would be freer from ordinary disturbances than our pendulums. It is evident from the considerations above that the coefficient of a radioactive transformation has a value which varies according to the system of reference and gives us no means of escaping from the unshakable relativity of time.

Quite apart from Einstein, thanks to whom we can no longer doubt that even infinitely precise apparatus would not measure anything but relative time, astronomical observations prove the impossibility of obtaining a standard of absolute duration.

We define the second as the 86,400th part of the mean solar day. We measure it and put it on clocks by means of the astronomical observation of the daily motion of the stars, that is to say, the rotation of the earth.

We therefore implicitly admit that the rotation of the earth is our constant standard of time. But the constancy of this standard is only approximate. The friction of the tides against the bottom of the ocean and the coasts tends gradually to retard the earth's rotation until the earth shall finally rotate on its axis in the same time as it takes the moon to revolve round the earth. The month and the day will then be of the same length, and each will last about as long as two of our present months. Unless something unforeseen happens, that will not take place for an enormous number of centuries. But even now we can, by comparing the revolution of the moon with what it was formerly, prove that it is being accelerated. Every century the moon is several seconds of arc ahead of what it ought to be by the law of gravitation.

This is explained by supposing that it is not the moon's motion which is accelerated but the earth's rotation which has slowed down, thus producing the same result. It is sufficient that the period of the earth's rotation should diminish by a small fraction of a second per century to account for the acceleration of the moon's motion. The necessarily approximate calculations made in this connection show that by the retarding effect of the tides the duration of the earth's rotation must be lengthened by one second every 500,000 years. In practical life, this is a small amount. But to the philosophers it means a good deal, because it shows that in the end we find in nature no standard, no fixed unit for measurement of time.

The second as we have seen it defined presupposes the rigorous exactness of Newton's law of gravitation, which is only a truth of experience, and therefore approximate. The best proof of this is that Einstein has been obliged to revise this law.

Thus we are unable to define those units of time which we call the hour, the minute, and the second, except for a small period in the history of the world.

In the eternal wave which rocks us, carries us along and soon swallows us up there is no rock to which we can fasten our frail barque; the very buoys we put out to measure our course are only floating mirages; and on the mysterious foundation of things our anchors slide along and fail to bite.

Printed in Great Britain by Hazell, Watson & Viney, Ld., London and Aylesbury.

THE HEAVENS. By J. H. FABRE, Author of "The Wonders of Instinct," etc. Translated by E. E. Fournier d'Albe. Demy 8vo, cloth. 15*s*. net.

This book teaches astronomy in a manner characteristic of the great naturalist. It is notoriously difficult to render the movements of the stars and planets intelligible to the untrained mind, but Fabre takes nothing for granted. He builds his teaching entirely on common everyday observation and leads his pupils by easy stages to the greatest heights of the Sublime Science.

THE WONDER BOOK OF PLANT LIFE. By J. H. FABRE, Author of "The Wonders of Instinct," etc. Translated by Bernard Miall. Illustrated. Demy 8vo, cloth. 15*s*. net.

This volume shows us yet another aspect of the "incomparable observer"—to quote no less an authority than Darwin. Fabre the botanist is no less delightful than Fabre the entomologist, and the tens of thousands of readers who lament that his great masterpiece has not been published in its entirety will find that there is still a treat in store for them.

HAUNTED HOUSES. By CAMILLE FLAMMARION, Author of "Death and its Mystery" and "Dreams of an Astronomer." Demy 8vo, cloth. 12*s*. 6*d*. net.

This volume consists mostly of the depositions of various persons who have communicated their experiences to the author. The stories range over a great number of years and come from all parts of the world (though principally, as is natural, from France). M. Flammarion adds his own observations in each case, but he does not come to any very definite conclusion beyond his belief that such a mass of testimony cannot be disregarded or denied.

To those who have already read the author's famous Trilogy ("Before Death," "At Death," and "After Death") M. Flammarion's writings of the Spirit World will need no introduction. It will be sufficient to say that he treats this subject from the same viewpoint of cases of phenomenal appearances from the Spirit World. Apart from this the book will be found to contain a most interesting number of Ghost Stories and unaccountable happenings.

T. FISHER UNWIN, LTD., 1 ADELPHI TERRACE, LONDON

27