First Dream

TOY UNIVERSE*

MR TOMPKINS, the little clerk of a big city bank, was very tired. The whole day's work of adding the infinite columns of bank accounts had brought his mind to a state of blank dullness. He definitely needed some distraction. Picking up an evening newspaper he opened the movie-theatre page. None of the films, however, looked attractive to him. He detested all this Hollywood stuff with infinite romances between the popular stars. If only there were at least one film with some real adventures, with something unusual and maybe even fantastic! But there was none. Unexpectedly, his eye fell on a little notice in the corner of the page. The local university was announcing a series of lectures on the problems of modern physics, and to-night's lecture was to be about the problems of Space and Time and Cosmology. Well, this might be something! He vaguely remembered that in his youth he had read a book about an adventurous astronomer travelling in a rocket-ship through interstellar space, visiting different planets and even some distant stars. Yes! he would go to this lecture, it might be just what he needed.

All this Hollywood stuff!

* The universe described below corresponds to a velocity of light ten million times smaller, and a gravitational constant a million million times larger than in our universe. The radius of the universe in the state of largest expansion is about a hundred miles and the corresponding density of dust about 1 lb. per cubic mile. The period of pulsation of the universe is in this case about 2 hours. The density of the rocks is the same as on the earth.

He arrived at the big university lecture room after the lecture* had already begun. The room was full of students, mostly young, listening with great attention to the tall, white-bearded man near the blackboard. When he entered, the professor was just busy writing a horrible-looking mathematical formula on the blackboard, something like this: $R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = \kappa T_{\mu\nu}$. Mr Tompkins's mathematical knowledge was limited to the four fundamental operations of arithmetic (of which he was using only the first two in his bank work), and the meaning of this funny-looking formula remained mysterious to him. He vaguely hoped that after covering all the blackboard with formulae, still more complicated than the first one, the professor would finally start to speak about some more understandable questions and would give a picture of the universe that he probably had in his mind.

This, however, he did not do, and, apart from the often-repeated sentence, "*the space in which we live is curved, closed in itself and in addition expanding*", Mr Tompkins could not learn anything that made any sense to him. It was not that this often-repeated sentence was much clearer to him than the rest of the lecture, but it made a deep impression on his mind. On the way home he tried to imagine the curved space, but could not go any further than thinking about it as something that looked like the bent buffer-bar on an old Ford. . . . No, he should not have gone to this lecture; the high-lights of Science were not for him. In this state of mental depression he undressed and pulled the blanket over his head.

* * * * *

Mr Tompkins awoke with the strange feeling of lying on something hard. He opened his eyes and found himself prostrated on what he first thought to be a big rock on the seashore. Later he discovered that it was actually a very big rock, about 30 feet in diameter, suspended in space without any visible support. The rock was covered with some green moss, and in a few places little bushes were growing from cracks in the stone.

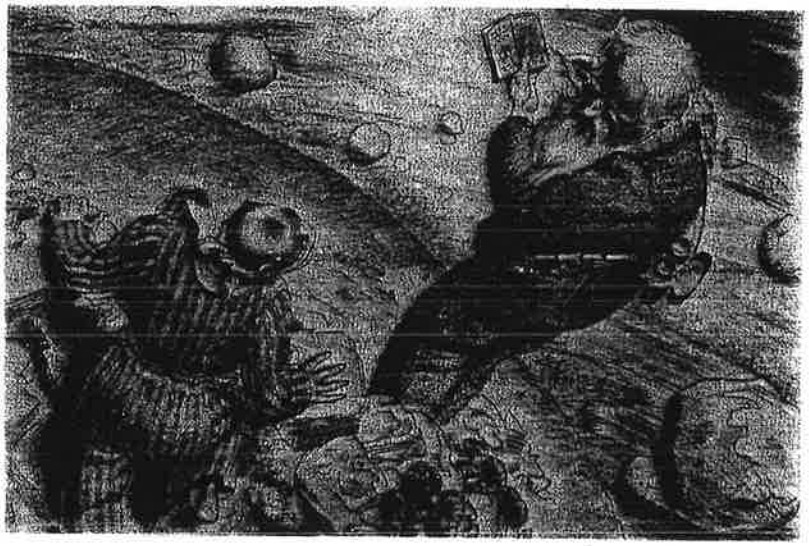
* Lecture II, p. 66.

The space around the rock was illuminated by some glimmering light and was very dusty. In fact, there was more dust in the air than he had ever seen, even in the films representing dust storms in the middle west. He tied his handkerchief round his nose and felt, after this, considerably relieved. But there were more dangerous things than the dust in the surrounding space. Very often stones of the size of his head and larger were swirling through the space near his rock, occasionally hitting it with a strange dull sound of impact. He noticed also one or two rocks of approximately the same size as his own, floating through space at some distance away. All this time, inspecting his surroundings, he was clinging hard to some protruding edges of his rock in constant fear of falling off and being lost in the dusty depths below. Soon, however, he became bolder, and made an attempt to crawl to the edge of his rock and to see whether there was really nothing underneath, supporting it. As he was crawling in this way, he noticed, to his great surprise, that he did not fall off, but that his weight was constantly pressing him to the surface of the rock, although he covered already more than a quarter of its circumference. Looking from behind a ridge of loose stones on the spot just underneath the place where he originally found himself, he discovered nothing to support the rock in space. To his great surprise, however, the glimmering light revealed the tall figure of a man with a long white beard, standing apparently with his head down and making some notes in his pocket-book. He recognized the professor whose lecture he had attended in the evening.

Now Mr Tompkins began slowly to understand. He remembered that he was taught in his schooldays that the earth is a big round rock moving freely in space around the sun. He also remembered the picture of two antipodes standing on the opposite sides of the earth. Yes, his rock was just a very small stellar body attracting everything to its surface, and he and the old professor were the only population of this little planet. This consoled him a little; there was at least no danger of falling off!

"Good morning," said Mr Tompkins, to divert the old man's attention from his calculations.

The professor raised his eyes from his note-book. "There are no mornings here," he said, "there is no sun and not a single luminous star in this universe. It is lucky that the bodies here show some chemical process



There are no mornings here

on their surface, otherwise I should not be able to observe the expansion of this space", and he returned again to his note-book.

Mr Tompkins felt quite unhappy; to meet the only living person in the whole universe, and to find him so unsociable! Unexpectedly, one of the little meteorites came to his help; with a crashing sound the stone hit the book in the hands of the professor and threw it, travelling fast through space, away from their little planet. "Now you will never see it again", said Mr Tompkins as the book got smaller and smaller, flying through space.

"On the contrary", replied the professor. "You see, the space in which we now are is not infinite in its extension. Oh yes, yes, I know that you have been taught in school that space is infinite, and that two parallel lines never meet. This, however, is not true either for the space in which the rest of humanity lives, or for the space in which we are now. The first one is of course very large indeed; the scientists estimated its present dimensions to be about 10,000,000,000,000,000,000,000 miles, which, for an ordinary mind, is fairly infinite. If I had lost my book there, it would take an incredibly long time to come back. Here, however, the situation is rather different. Just before the note-book was torn out of my hands, I had figured out that this space is only about five miles in diameter, though it is rapidly expanding. I expect the book back in not more than half an hour."

"But", ventured Mr Tompkins, "do you mean that your book is going to behave like the boomerang of an Australian native, and, by moving along a curved trajectory, fall down at your feet?"

"Nothing of the sort", answered the professor. "If you want to understand what really happens, think about an ancient Greek who did not know that the earth was a sphere. Suppose he has given somebody instructions to go always straight northwards. Imagine his astonishment when his runner finally returns to him from the south. Our ancient Greek did not have a notion about travelling round the world (round the earth, I mean in this case), and he would be sure that his runner had lost his way and had taken a curved route which brought him back. In reality his man was going all the time along the straightest line one can draw on the surface of the earth, but he travelled round the world and thus came back from the opposite direction. The same thing is going to happen to my book, unless it is hit on its way by some other stone and thus deflected from the straight track. Here, take these binoculars, and see if you can still see it."

Mr Tompkins put the binoculars to his eyes, and, through the dust which somewhat obscured the whole picture, he managed to see the professor's note-book travelling through space far far away. He was some-

what surprised by the pink colouring of all the objects, including the book, at that distance.

"But", he exclaimed after a while, "your book is returning, I see it growing larger."

"No", said the professor, "it is still going away. The fact that you see it growing in size, as if it were coming back, is due to a peculiar focusing effect of the closed spherical space on the rays of light. Let us return to our ancient Greek. If the rays of light could be kept going all the time along the curved surface of the earth, let us say by refraction of the atmosphere, he would be able, using powerful binoculars, to see his runner all the time during the journey. If you look on the globe, you will see that the straightest lines on its surface, the meridians, first diverge from one pole, but, after passing the equator, begin to converge towards the opposite pole. If the rays of light travelled along the meridians, you, located, for example, at one pole, would see the person going away from you growing smaller and smaller only until he crossed the equator. After this point you would see him growing larger and it would seem to you that he was returning, going, however, backwards. After he had reached the opposite pole, you would see him as large as if he were standing right by your side. You would not be able, however, to touch him, just as you cannot touch the image in a spherical mirror. On this basis of two-dimensional analogy, you can imagine what happens to the light rays in the strangely curved three-dimensional space. Here, I think the image of the book is quite close now." In fact, dropping the binoculars, Mr Tompkins could see that the book was only a few yards away. It looked, however, very strange indeed! The contours were not sharp, but rather washed out, the formulae written by the professor on its pages could be hardly recognized, and the whole book looked like a photograph taken out of focus and underdeveloped.

"You see now", said the professor, "that this is only the image of the book, badly distorted by light travelling across one half of the universe. If you want to be quite sure of it, just notice how the stones behind the book can be seen through its pages."

Mr Tompkins tried to reach the book, but his hand passed through the image without any resistance.

"The book itself", said the professor, "is now very close to the opposite pole of the universe, and what you see here are just two images of it. The second image is just behind you and when both images coincide, the real book will be exactly at the opposite pole." Mr Tompkins didn't hear; he was too deeply absorbed in his thoughts, trying to remember how the images of objects are formed in elementary optics by concave mirrors and lenses. When he finally gave it up, the two images were again receding in opposite directions.

"But what makes the space curved and produce all these funny effects?" he asked the professor.

"The presence of ponderable matter", was the answer. "When Newton discovered the law of gravity, he thought that gravity was just an ordinary force, the same type of force as, for example, is produced by an elastic string stretched between two bodies. There always remains, however, the mysterious fact that all bodies, independent of their weight and size, have the same acceleration and move the same way under the action of gravity, provided you eliminate the friction of air and that sort of thing, of course. It was Einstein who first made it clear that the primary action of ponderable matter is to produce the curvature of space and that the trajectories of all bodies moving in the field of gravity are curved just because space itself is curved. But I think it is too hard for you to understand, without knowing sufficient mathematics."

"It is", said Mr Tompkins. "But tell me, if there were no matter, would we have the kind of geometry I was taught at school, and would parallel lines never meet?"

"They would not," answered the professor, "but neither would there be any material creature to check it."

"Well, perhaps Euclid never existed, and therefore could construct the geometry of absolutely empty space?"

But the professor apparently did not like to enter into this metaphysical discussion.

In the meantime the image of the book went off again far away in the original direction, and started coming back for the second time. Now it was still more damaged than before, and could hardly be recognized at all, which, according to the professor, was due to the fact that the light rays had travelled this time round the whole universe.

"If you turn your head once more," he said to Mr Tompkins, "you will see my book finally coming back after completing its journey round the world." He stretched his hand, caught the book, and pushed it into his pocket. "You see," he said, "there is so much dust and stone in this universe that it makes it almost impossible to see round the world. These shapeless shadows which you might notice around us are most probably the images of ourselves, and surrounding objects. They are, however, so much distorted by dust and irregularities of the curvature of space that I cannot even tell which is which."

"Does the same effect occur in the big universe in which we used to live before?" asked Mr Tompkins.

"Oh yes," was the answer, "but that universe is so big that it takes the light milliards of years to go round. You could have seen the hair cut on the back of your head without any mirror, but only milliards of years after you had been to the barber. Besides, most probably the interstellar dust would completely obscure the picture. By the way, one English astronomer even supposed once, mostly as a joke, that some of the stars which can be seen in the sky at present are only the images of stars which existed long ago."

* * * * *

Tired of the efforts to understand all these explanations, Mr Tompkins looked around and noticed, to his great surprise, that the picture of the sky had considerably changed. There seemed to be less dust about, and he took off the handkerchief which was still tied round his face. The small stones were passing much less frequently and hitting the surface of their

rock with much less energy. Finally, a few big rocks, like their own, which he had noticed in the very beginning, had gone much farther away and could hardly be seen at this distance.

"Well, life is certainly becoming more comfortable", thought Mr Tompkins, "I was always so scared that one of those travelling stones would hit me. Can you explain the change in our surroundings?" he said, turning to the professor.

"Very easily; our little universe is rapidly expanding and since we have been here its dimensions have increased from *five to about a hundred miles*. As soon as I found myself here, I noticed this expansion from the reddening of the distant objects."

"Well, I also see that everything is getting pink, at great distances," said Mr Tompkins, "but why does it signify expansion?"

"Have you ever noticed", said the professor, "that the whistle of an approaching train sounds very high, but after the train passes you, the tone is considerably lower? This is the so-called Doppler Effect: the dependence of the pitch on the velocity of the source. When the whole space is expanding, every object located in it moves away with a velocity proportional to its distance from the observer. Therefore the light emitted by such objects is getting redder, which in optics corresponds to a lower pitch. The more distant the object is, the faster it moves and the redder it seems to us. In our good old universe, which is also expanding, this reddening, or the red-shift as we call it, permits astronomers to estimate the distances of the very remote clouds of stars. For example, one of the nearest clouds, the so-called Andromeda nebula, shows 0·05 % of reddening, which corresponds to the distance which can be covered by light in eight hundred thousand years. But there are also nebulae just on the limit of present telescopic power, which show a reddening of about 15 % corresponding to distances of several hundred millions of light years. Presumably, these nebulae are located almost on the halfway point of the equator of the big universe, and the total volume of space which is known to terrestrial astronomers represents a considerable part of the total volume of that

universe. The present rate of expansion is about 0·000,000,01 % per year, so that each second the radius of the universe increases by *ten million* miles. Our little universe grows comparatively much faster, gaining in its dimensions about 1 % per minute."

"Will this expansion never stop?" asked Mr Tompkins.

"Of course it will", said the professor. "And then the contraction will start. Each universe pulsates between a very small and a very large radius. For the big universe the period is rather large, something like several thousand million years, but our little one has a period of only about two hours. I think we are now observing the state of largest expansion. Do you notice how cold it is?"

In fact, the thermal radiation filling up the universe, and now distributed over a very large volume, was giving only very little heat to their little planet, and the temperature was at about freezing-point.

"It is lucky for us", said the professor, "that there was originally enough radiation to give some heat even at this stage of expansion. Otherwise it might become so cold that the air around our rock would condense into liquid and we would freeze to death. But the contraction has already begun, and it will soon be warm again."

Looking at the sky, Mr Tompkins noticed that all distant objects changed their colour from pink to violet which, according to the professor, was due to the fact that all the stellar bodies had started moving towards them. He also remembered the analogy given by the professor of the high pitch of the whistle of an approaching train, and shuddered from fear.

"If everything is contracting now, shouldn't we expect that soon all the big rocks filling the universe will come together and that we shall be crushed between them?" he asked the professor anxiously.

"Exactly so," answered the professor calmly, "but I think that even before this the temperature will rise so high that we shall both be dissociated into separate atoms. This is a miniature picture of the end of the big universe—everything will be mixed up into a uniform hot gas sphere, and only with a new expansion will new life begin again."

"Oh my!" muttered Mr Tompkins—"In the big universe we have, as you mentioned, milliards of years before the end, but here it is going too fast for me! I feel hot already, even in my pyjamas."

"Better not take them off," said the professor, "it will not help. Just lie down and observe as long as you can."

Mr Tompkins did not answer; the hot air was unbearable. The dust, which became very dense now, was accumulating around him, and he felt as if he were being rolled up in a soft warm blanket. He made a motion to free himself, and his hand came out into cool air.

"Did I make a hole in that inhospitable universe?" was his first thought. He wanted to ask the professor about it, but could not find him anywhere. Instead, in the dim light of the morning, he recognized the contours of the familiar bedroom furniture. He was lying in his bed tightly rolled up in a woollen blanket, and had just managed to free one hand from it.

"New life begins with expansion", he thought, remembering the words of the old professor. "Thank God we are still expanding!" And he went to take his morning bath.

Third Dream

CITY SPEED LIMIT*

MR TOMPKINS liked his dreams and was anxiously awaiting next week to get some more material for his night adventures. But he was very disappointed to find that the lecture on quantum theory was the last, and that there would be no more lectures that year. His disappointment was allayed a little, however, when he managed to get a manuscript of the first lecture, which he had missed.

This morning the big hall of the bank was almost empty and Mr Tompkins, hidden behind his little window, opened the thick manuscript and tried to get through the impenetrable hedge of formulae and complicated geometrical figures by which the professor attempted to explain the theory of relativity to his students. But he only got as far as understanding that the whole point of this lecture was that there is a maximum velocity, the velocity of light, which cannot be surpassed by any moving material body, and that this fact leads to very strange and unusual consequences. It was stated, however, that as the velocity of light is 186,000 miles per second, the relativity effects could hardly be observed for events of ordinary life. But the nature of these unusual effects was really much more difficult to understand, and it seemed to Mr Tompkins that all this was contradictory to common sense. He was trying to imagine the contraction of measuring rods and the odd behaviour of clocks—effects which should be expected if they move with a velocity close to that of light—when his head slowly dropped on the type-written pages.

* * * * *

When he opened his eyes again he found himself standing at a street corner in a beautiful old city. He suspected that he was dreaming now, but

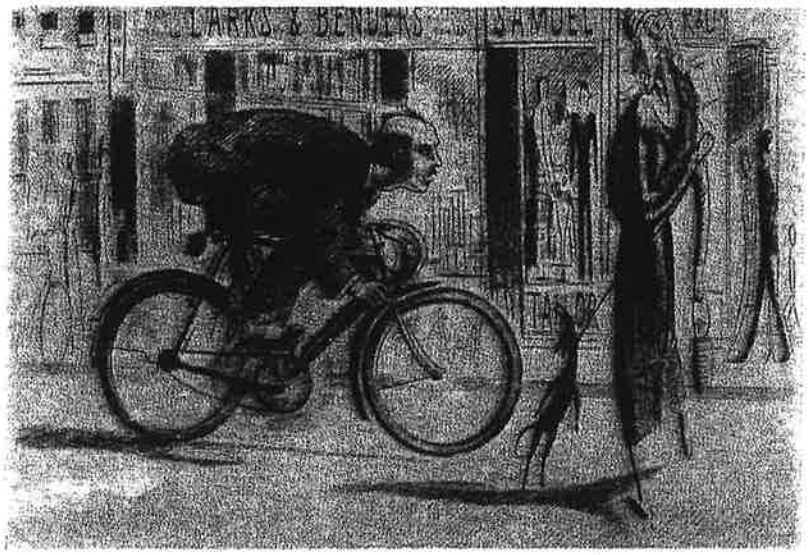
* In this story the velocity of light is about 10 miles per hour, the other world constants are as usual.

to his surprise there was nothing unusual happening around him; even a policeman standing on the opposite corner looked as policemen usually do. The hands of the big clock on the tower down the street were pointing almost to noon and the streets were nearly empty. A single cyclist was

Unbelievably flattened

coming slowly down the street and, as he approached, Mr Tompkins's eyes opened wide with astonishment. For the bicycle and the young man on it were unbelievably flattened in the direction of the motion, as if seen through a cylindrical lens. The clock on the tower struck twelve, and the cyclist, evidently in a hurry, stepped harder on the pedals. Mr Tompkins did not notice that he gained much in speed, but, as the result of his effort, he flattened still more and went down the street looking exactly like a

picture cut out of cardboard. Then Mr Tompkins felt very proud because he could understand what was happening to the cyclist—it was simply the contraction of moving bodies, about which he had just read. "Evidently nature's speed limit is lower here," he concluded, "that is why the bobby



The city blocks became still shorter

on the corner looks so lazy, he need not watch for speeders." In fact, a taxi moving along the street at the moment and making all the noise in the world could not do much better than the cyclist, and was just crawling along. Mr Tompkins decided to overtake the cyclist, who looked a good sort of fellow, and ask him all about it. Making sure that the policeman was looking the other way, he borrowed somebody's bicycle standing near

the kerb and sped down the street. He expected that he would be immediately flattened, and was very happy about it as his increasing figure had lately caused him some anxiety. To his great surprise, however, nothing happened to him or to his cycle. On the other hand, the picture around him completely changed. The streets grew shorter, the windows of the shops began to look like narrow slits, and the policeman on the corner became the thinnest man he had ever seen.

"By Jove!" exclaimed Mr Tompkins excitedly, "I see the trick now. This is where the word *relativity* comes in. Everything that moves relative to me gets shorter for me, whoever works the pedals!" He was a good cyclist and was doing his best to overtake the young man. But he found that it was not at all easy to get up speed on this bicycle. Although he was working on the pedals as hard as he possibly could, the increase in speed was almost negligible. His legs already began to ache, but still he could not manage to pass a lamp-post on the corner much faster than when he had just started. It looked as if all his efforts to move faster were leading to no result. He understood now very well why the cyclist and the cab he had just met could not do any better, and he remembered the words of the professor about the impossibility of surpassing the limiting velocity of light. He noticed, however, that the city blocks became still shorter and the cyclist riding ahead of him did not now look so far away. He overtook the cyclist at the second turning and, when they had been riding side by side for a moment, was surprised to see that he was quite a normal, sporting-looking young man. "Oh, that must be because we do not move relative to each other", he concluded; and he addressed the young man.

"Excuse me, sir!" he said, "Don't you find it inconvenient to live in a city with such a slow speed limit?"

"Speed limit?" returned the other in surprise, "we don't have any speed limit here. I can get anywhere as fast as I wish, or at least I could if I had a motor-cycle instead of this nothing-to-be-done-with old bike!"

"But you were moving very slowly when you passed me a moment ago", said Mr Tompkins. "I noticed you particularly."

"Oh you did, did you?" said the young man, evidently offended. "I suppose you haven't noticed that since you first addressed me we have passed five blocks. Isn't that fast enough for you?"

"But the streets became so short," argued Mr Tompkins.

"What difference does it make anyway, whether we move faster or whether the street becomes shorter? I have to go ten blocks to get to the post office, and if I step harder on the pedals the blocks become shorter and I get there quicker. In fact, here we are", said the young man getting off his bike.

Mr Tompkins looked at the post office clock, which showed half-past twelve. "Well!" he remarked triumphantly, "it took you half an hour to go this ten blocks, anyhow—when I saw you first it was exactly noon!"

"And did you *notice* this half hour?" asked his companion. Mr Tompkins had to agree that it had really seemed to him only a few minutes. Moreover, looking at his wrist watch he saw that it was showing only five minutes past twelve. "Oh!" he said, "is the post office clock fast?" "Of course it is, or your watch is too slow, just because you have been going too fast. What's the matter with you, anyway? Did you fall down from the moon?" and the young man went into the post office.

After this conversation, Mr Tompkins realized how unfortunate it was that his old friend the professor was not at hand to explain all these strange events to him. The young man was evidently a native, and had been accustomed to this state of things even before he had learned to walk. So Mr Tompkins was forced to explore this strange world by himself. He put his watch right by the post office clock and, to make sure that it went all

right, waited for ten minutes. His watch did not lose. Continuing his journey down the street he finally saw the railway station and decided to check his watch again. To his surprise it was again quite a bit slow. "Well, this must be some relativity effect, too," concluded Mr Tompkins; and decided to ask about it from somebody more intelligent than the young cyclist.

Dear Grandfather!

The opportunity came very soon. A gentleman obviously in his forties got out of the train and began to move towards the exit. He was met by a very old lady, who, to Mr Tompkins's great surprise, addressed him as "dear Grandfather". This was too much for Mr Tompkins. Under the excuse of helping with the luggage, he started a conversation.

"Excuse me, if I am intruding into your family affairs," said he, "but are you really the grandfather of this nice old lady? You see, I am a stranger here, and I never...." "Oh, I see", said the gentleman, smiling with his moustache. "I suppose you are taking me for the Wandering Jew or something. But the thing is really quite simple. My business requires me to travel quite a lot, and, as I spend most of my life in the train, I naturally grow old much more slowly than my relatives living in the city. I am so glad that I came back in time to see my dear little grand-daughter still alive! But excuse me, please, I have to attend to her in the taxi", and he hurried away leaving Mr Tompkins alone again with his problems. A couple of sandwiches from the station buffet somewhat strengthened his mental ability, and he even went so far as to claim that he had found the contradiction in the famous principle of relativity.

"Yes, of course," thought he, sipping his coffee, "if all were relative, the traveller would appear to his relatives as a very old man, and they would appear very old to him, although both sides might in fact be fairly young. But what I am saying now is definitely nonsense: One could not have relative whiskers!" So he decided to make a last attempt to find out how things really are, and turned to a solitary man in railway uniform sitting in the buffet.

"Will you be so kind, sir," he began, "will you be good enough to tell me who is responsible for the fact that the passengers in the train grow old so much more slowly than the people staying at one place?"

"I am responsible for it", said the man, very simply.

"Oh!" exclaimed Mr Tompkins. "So you have solved the problem of the Philosopher's Stone of the ancient alchemists. You should be quite a famous man in the medical world. Do you occupy the chair of medicine here?"

"No," answered the man, being quite taken aback by this, "I am just a brakeman on this railway."

"Brakeman! You mean a brakeman..." exclaimed Mr Tompkins, losing all the ground under him. "You mean you—just put the brakes on when the train comes to the station?"

"Yes, that's what I do: and every time the train gets slowed down, the passengers gain in their age relative to other people. Of course," he added modestly, "the engine driver who accelerates the train also does his part in the job."

"But what has it to do with staying young?" asked Mr Tompkins in great surprise.

"Well, I don't know exactly," said the brakeman, "but it is so. When I asked a University professor travelling in my train once, how it comes about, he started a very long and incomprehensible speech about it, and finally said that it is the same thing as the 'redshifts'—I think he called it—on the sun. Have you heard anything about such things as redshifts?"

"No-o", said Mr Tompkins, a little doubtfully; and the brakeman went away shaking his head. A big, sombre-looking waiter came to his table with a bill, and Mr Tompkins began to search in his pockets for change. Not finding any, he asked the gloomy waiter whether a cheque would do.

"No," barked the waiter, "give me cash!"

"But I haven't *got* any cash", said Mr Tompkins, getting a bit scared.

"Cash!" shouted the waiter. "Cash!...Cash it, please!" said the irritated voice again, and Mr Tompkins raised his head from the table. Across the table stood, not the gloomy waiter, but his old friend the professor, pushing a cheque towards him.

"Oh! I *am* so glad to see you!" exclaimed Mr Tompkins; "I just wanted to ask you if one can get eternal life simply by running round all the time?"

"Sorry, I don't get you", said the professor. "Will you please cash this cheque? I am in a hurry for a meeting."

Yes, in real life the old professor was much less friendly than in dreams. Mr Tompkins sighed, and started to count out the banknotes.

Fifth Dream

Mr TOMPKINS TAKES A HOLIDAY*

MR TOMPKINS was very amused about his adventures in the relativistic city, but was very sorry that the professor had not been with him to give any explanation of the strange things he had observed: the mystery of how the railway brakeman had been able to prevent the passengers from getting old worried him especially. Many a night he went to bed with the hope that he would see this interesting city again, but the dreams were rare and mostly unpleasant; last time it was the manager of the bank who was firing him for the uncertainty he introduced into the bank accounts...so now he decided that he had better take a holiday, and go for a week somewhere to the sea. Thus he found himself sitting in a compartment of a train and watching through the window the grey roofs of the city suburb gradually giving place to the green meadows of the countryside. He picked up a newspaper and tried to interest himself in the French-Italian conflict. But it all seemed to be so dull, and the railway carriage rocked him pleasantly....

When he lowered the paper and looked out of the window again the landscape had changed considerably. The telegraph poles were so close to each other that they looked like a hedge, and the trees had extremely narrow crowns and were like Italian cypresses. Opposite to him sat his old friend the professor, looking through the window with great interest. He had probably got in while Mr Tompkins was busy with his newspaper.

"We are in the land of relativity," said Mr Tompkins, "aren't we?"

"Oh!" exclaimed the professor, "you know so much already! Where did you learn it from?"

* The conditions here are the same as in the Third Dream: the velocity of light is about 10 miles per hour, the other world constants are as usual.

"I have already been here once, but did not have the pleasure of your company then."

"So you are probably going to be my guide this time", the old man said.

. . .were so close to each other that they looked like a hedge

"I should say not", retorted Mr Tompkins. "I saw a lot of unusual things, but the local people to whom I spoke could not understand what my trouble was at all."

"Naturally enough", said the professor. "They are born in this world and consider all the phenomena happening around them as self-evident. But I imagine they would be quite surprised if they happened to get into

the world in which you used to live. It would look so remarkable to them."

"May I ask you a question?" said Mr Tompkins. "Last time I was here, I met a brakeman from the railway who insisted that owing to the fact that the train stops and starts again the passengers grow old less quickly than the people in the city. Is this magic, or is it also consistent with modern science?"

"There is never any excuse for putting forward magic as an explanation", said the professor. "This follows directly from the laws of physics. It was shown by Einstein, on the basis of his analysis of new (or should I say as old-as-the-world but newly discovered) notions of space and time, that all physical processes slow down when the system in which they are taking place is changing its velocity. In our world the effects are almost unobservably small, but here, owing to the small velocity of light, they are usually very obvious. If, for example, you tried to boil an egg here, and, instead of letting the saucepan stand quietly on the stove, moved it to and fro, constantly changing its velocity, it would take you not five but perhaps six minutes to boil it properly. Also in the human body all processes slow down, if the person is sitting (for example) in a rocking chair or in a train which changes its speed; we live more slowly under such conditions. As, however, all processes slow down to the same extent, physicists prefer to say that *in a non-uniformly moving system time flows more slowly*."

"But do scientists actually observe such phenomena in our world at home?"

"They do, but it requires considerable skill. It is technically very difficult to get the necessary accelerations, but the conditions existing in a non-uniformly moving system are analogous, or should I say identical, to the result of the action of a very large force of gravity. You may have noticed that when you are in an elevator which is rapidly accelerated upwards it seems to you that you have grown heavier; on the contrary, if the elevator starts downwards (you realize it best when the rope breaks) you feel as though you were losing weight. The explanation is that the gravitational

field created by acceleration is added to or subtracted from the gravity of the earth. Well, the potential of gravity on the sun is much larger than on the surface of the earth and all processes there should be therefore slightly slowed down. Astronomers do observe this."

"But they cannot go to the sun to observe it?"

"They do not need to go there. They observe the light coming to us from the sun. This light is emitted by the vibration of different atoms in the solar atmosphere. If all processes go slower there, the speed of atomic vibrations also decreases, and by comparing the light emitted by solar and terrestrial sources one can see the difference. Do you know, by the way"—the professor interrupted himself—"what the name of this little station is that we are now passing?"

The train was rolling along the platform of a little countryside station which was quite empty except for the station master and a young porter sitting on a luggage trolley and reading a newspaper. Suddenly the station master threw his hands into the air and fell down on his face. Mr Tompkins did not hear the sound of shooting, which was probably lost in the noise of the train, but the pool of blood forming round the body of the station master left no doubt. The professor immediately pulled the emergency cord and the train stopped with a jerk. When they got out of the carriage the young porter was running towards the body, and a country policeman was approaching.

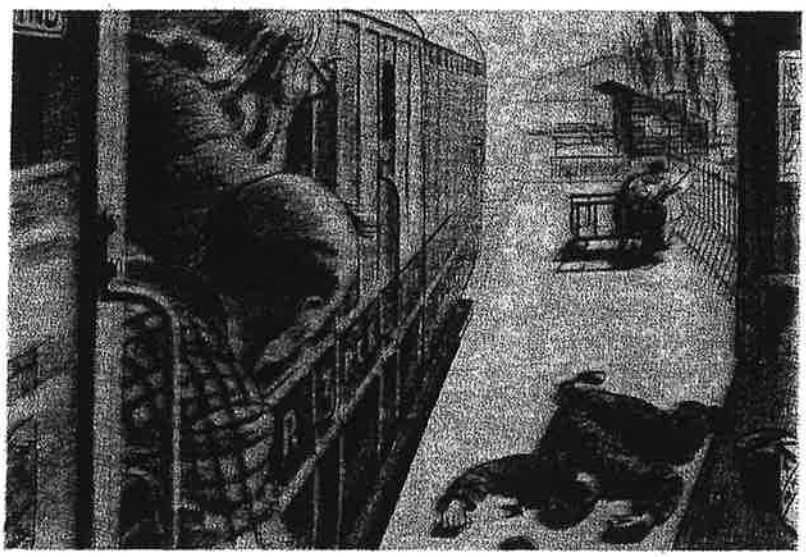
"Shot through the heart", said the policeman after inspecting the body, and, putting a heavy hand on the porter's shoulder, he went on: "I am arresting you for the murder of the station master."

"I didn't kill him", exclaimed the unfortunate porter. "I was reading a newspaper when I heard the shot. These gentlemen from the train have probably seen all and can testify that I am innocent."

"Yes", said Mr Tompkins, "I saw with my own eyes that this man was reading his paper when the station master was shot. I can swear it on the Bible."

"But you were in the moving train", said the policeman, taking an

authoritative tone, "and what you saw is therefore no evidence at all. As seen from the platform the man could have been shooting at the very same moment. Don't you know that simultaneousness depends on the system from which you observe it? Come along quietly", he said, turning to the porter.



The pool of blood forming round the body of the station master left no doubt

"Excuse me, constable", interrupted the professor, "but you are absolutely wrong, and I do not think that at headquarters they will like your ignorance. It is true, of course, that the notion of simultaneousness is highly relative in your country. It is also true that two events in different places could be simultaneous or not, depending on the motion of the

observer. But, even in your country, no observer could see the consequence before the cause. You have never received a telegram before it was sent, have you? or got drunk before opening the bottle? As I understand you, you suppose that owing to the motion of the train the shooting would have been seen by us much *later* than its effect and, as we got out of the train immediately we saw the station master fall, we still had not seen the shooting itself. I know that in the police force you are taught to believe only what is written in your instructions, but look into them and probably you will find something about it."

The professor's tone made quite an impression on the policeman and, pulling out his pocket book of instructions, he started to read it slowly through. Soon a smile of embarrassment spread out across his big, red face.

"Here it is," said he, "section 37, subsection 12, paragraph *e*: 'As a perfect alibi should be recognized any authoritative proof, from any moving system whatsoever, that at the moment of the crime or within a time interval $\pm cd$ (c being natural speed limit and d the distance from the place of the crime) the suspect was seen in another place.'"

"You are free, my good man", he said to the porter, and then, turning to the professor: "Thank you very much, Sir, for saving me from trouble with headquarters. I am new to the force and not yet accustomed to all these rules. But I must report the murder anyway", and he went to the telephone box. A minute later he was shouting across the platform. "All is in order now! They caught the real murderer when he was running away from the station. Thank you once more!"

"I may be very stupid", said Mr Tompkins, when the train started again, "but what is all this business about simultaneousness? Has it really no meaning in this country?"

"It has", was the answer, "but only to a certain extent; otherwise I should not have been able to help the porter at all. You see, the existence of a natural speed limit for the motion of any body or the propagation of any signal, makes simultaneousness in our ordinary sense of the word lose its meaning. You probably will see it more easily this way. Suppose you

have a friend living in a far-away town, with whom you correspond by letter, mail train being the fastest means of communication. Suppose now that something happens to you on Sunday and you learn that the same thing is going to happen to your friend. It is clear that you cannot let him know about it before Wednesday. On the other hand, if he knew in advance about the thing that was going to happen to you, the last date to let you know about it would have been the previous Thursday. Thus for six days, from Thursday to next Wednesday, your friend was not able either to influence your fate on Sunday or to learn about it. From the point of view of causality he was, so to speak, excommunicated from you for six days."

"What about a telegram?" suggested Mr Tompkins.

"Well, I accepted that the velocity of the mail train was the maximum possible velocity, which is about correct in this country. At home the velocity of light is the maximum velocity and you cannot send a signal faster than by radio."

"But still," said Mr Tompkins, "even if the velocity of the mail train could not be surpassed, what has it to do with simultaneousness? My friend and myself would still have our Sunday dinners simultaneously, wouldn't we?"

"No, that statement would not have any sense then; one observer would agree to it, but there would be others, making their observations from different trains, who would insist that you eat your Sunday dinner at the same time as your friend has his Friday breakfast or Tuesday lunch. But in no way could anybody observe you and your friend simultaneously having meals more than three days apart."

"But how can all this happen?" exclaimed Mr Tompkins unbelievingly.

"In a very simple way, as you might have noticed from my lectures. The upper limit of velocity must remain the same as observed from different moving systems. If we accept this we should conclude that. . . ."

As the professor spoke these last words Mr Tompkins noticed some very strange changes in his face. His grey hair changed into a lovely golden

colour, his eyebrows suddenly became thin and nicely arched, and his eyelashes grew longer. Finally, his long beard disappeared and Mr Tompkins found himself looking into the face of a pretty young girl who had got in at the last station. She was inspecting him with surprise and a hidden smile. Mr Tompkins hurriedly picked up his newspaper from the floor and hid behind it for the rest of the journey. He was a very shy man, and very much afraid of women.