THE HEART ON THE OTHER SIDE

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The friends and colleagues of Niels Bohr (yes, the man who first pictured the "Bohr atom") had the happy habit of celebrating his birthday by contributing papers to a sort of star-studded birthday book printed for his private enjoyment. Many of the papers are downright earnest and perhaps more technical than we laymen might enjoy; but there are exceptions.

One was O. R. Frisch's On the Feasibility of Coal-Driven Power Stations, *elsewhere in this volume. Another is the present story by George Gamow who, if any scientist ever qualified, surely can be presented as "a man who needs no introduction." His deadpan topological romance,* The Heart on the Other Side, *was first written to celebrate Bohr's seventieth birthday, and is here published for a general audience for the first time.*

"But Father will never give his consent," said Vera Sapognikoff in a tone of despair.

"But he must," said Stan Situs. He was very much in love.

Vera shook her head. "What my father is looking for in the way of a son-in-law is someone who can help him in his shoe business, and eventually take it over. You're a mathematician. You can't possibly qualify as a shoe manufacturer, can you?"

"I guess I can't," Stan agreed sadly, after some thought. "Perhaps if I were in some other branch of mathematics—But I am a topologist. I don't see what topology has to contribute to the production and selling of shoes."

Then he added stubbornly: "But I can't give you up, Vera! I can't lose the girl I love just because there's no cash value in a Möbius twist!"

"A what?"

Stan said patiently: "A Möbius twist. Haven't I ever shown you one?" He scrabbed in his desk drawer. They were in his university office, and it took him only a moment to find a piece of paper, a pair of scissors and a small bottle of glue.

"Look," he said, and cut a strip of paper an inch or so wide. He twisted one end of it a half turn and glued it together, forming a twisted paper ring.

Vera looked at the paper and then at the man she loved. "Is this what you do for a living?" she asked.

"Here." Stan handed her the scissors. "Cut it all the way around, along the middle line of the strip. See what you get."

Vera shook her head. "That's silly. I know what I'll get. It will cut into two rings, and so what?"

"Cut," urged Stan.

Vera shrugged and did what Stan told her. And, curiously, it didn't work out at all the way she had expected. When the scissors had gone all the way around the strip, and closed on the starting point, Vera cried out. For there weren't two rings at all—there was still only one, but a ring that was half its former width and twice its former length.

Vera stared at her beloved mathematician. "What is this, magic? And who is this man Möbius?"

"He was a Swedish mathematician of the nineteenth century, who contributed a great deal to the science of topology. I'm afraid his other contributions, though, aren't quite as easy to demonstrate.

"But there's more to be said about this strip." Quickly Stan cut out and pasted a new one. "See here. Suppose I sketch a few cartoon figures on the strip. Now you have to use your imagination a little. Make believe the strip is cellophane, so that you can see figures drawn on both sides of it at once. Then imagine that the little drawings can slide freely along the surface."

"All right," said Vera, frowning.

"Do you see?" Stan demanded triumphantly. "You find that they turn into their *mirror images* each time they make a complete trip around the strip!"

"Is that right?" murmured Vera glassily. She was getting visibly discouraged with so much mathematics.

"Pay attention!" Stan commanded, forgetting for the moment that he was talking to a lovely girl he wanted to marry, and not to one of his classes of graduate students. "This is a very important property of a Möbius strip—which, as I am going to show in my next article, can be generalized for three-dimensional, or even for *n*-dimensional, space."

"That's nice," muttered Vera.

But Stan was hardly listening; he was carried away. "This is not merely a matter of academic interest," he said proudly. "According to my calculations, there *is* such a three-dimensional Möbius effect somewhere on the surface of the earth. You see the consequences, of course?"

"Of course."

"Suppose, for example," said Stan, sketching hastily, "I draw on this strip a man and an animal facing each other. You have to imagine, still, that this is cellophane—which corresponds to the fact that mathematical surfaces are not supposed to have any thickness, and therefore both figures should be visible from either side of the paper. I draw, then,

this gallant matador and brave bull in mortal conflict."

"Oh, how cute!" exclaimed Vera, delighted to find something she could recognize.

"Now," continued Stan, filled with lecturer's enthusiasm, "imagine that the matador runs all the way around the strip and comes back to the bull from the other direction. Then he will look either in flight from the bull, or confronting him—upside down.

"Since neither position is very suitable for fighting the bull, he will have to make another run around Möbius strip to straighten himself out again."

Vera began to gather her pocketbook and gloves in a businesslike way.

"That's very nice," she said politely. "But, Stan, what has it got to do with *us*? I can see how you amuse yourself with these Möbius comic strips. But you can't give a Möbius twist to a shoe to make Father agree to our marriage."

Stan came back to his present surroundings with a start.

"Oh," he said. "No, I suppose not. But—"

Then he frowned in concentration, and remained that way for several moments, until Vera became alarmed. "Stan?" she asked tentatively. "Stan?"

"But I can!" he cried. "Sure I can! Give a Möbius twist to a shoe, eh? Why, that's a brilliant idea—and, believe me, it will revolutionize the shoe industry!"

Not more than an hour later, Vera's father had a caller.

"Dr. Situs is here to see you," said the receptionist's voice through the intercom. "He says that he has a very important proposal to make."

"All right, let him in," Mr. Sapognikoff growled. He leaned back behind his giant desk, scowling. "I doubt, though," he said aloud, "that this young fellow has anything to propose but marriage." Then, still grumbling, he got up reluctantly as Stan came in and shook his hand.

Stan Situs said briskly: "Sir, I suppose you are aware that each man, as well as each woman, has two feet. One is right. The other is left."

Mr. Sapognikoff looked suddenly alarmed. "What?" he asked.

"It is a well known fact," Stan assured him. "Now, doesn't it make the production of shoes more expensive? Don't you need two separate sets of machinery—one for right shoes and one for left—and wouldn't it be simple if one needed to produce only, let us say, right-foot shoes?"

Mr. Sapognikoff, now quite persuaded that the boy was really out of his mind, though probably not dangerous, said with heavy humor: "Sure. And I guess we make everybody hop around on one foot after that, right?"

"No, sir," Stan assured him seriously. "That would not be practical."

"Then what's the point?"

Stan settled himself. "The point is that for the past few years I have been working on the mathematical possibility of a Möbius twist in a three-dimensional space. I will not trouble you by trying to explain it, since you wouldn't understand. For that matter, even your daughter didn't." Mr. Sapognikoff scowled but said nothing. "The fact is that, according to my recent calculations pertaining to the gravitational anomalies observed in certain regions of the earth's surface, such a three-dimensional Möbius twist of space must exist somewhere in the unexplored regions of the upper Amazon River. In fact, my conclusions are strongly supported by recent findings of South American biological expeditions which discovered in that locality two different kinds of snails with left-screw and right-screw shells."

Mr. Sapognikoff said ominously: "I'm a busy man, Situs. And I don't understand a word of what you're saying. What does it have to do with shoes?"

"Well," began Stan patiently, "a three-dimensional space turns things into their mirror image if they are carried

around the vortex point of the Möbius twist. Since right and left shoes are mirror images of one another, you can turn a right shoe into a left shoe, or vice versa, by carrying it around that vortex point in the upper Amazon. That's probably what had happened to the snails migrating in that vicinity. From now on, you can produce only right-foot shoes, and turn half of them into left-foot shoes by sending the lot up the Amazon River and around the vortex point. Think of the saving on machinery, and the perfect fit of shoe pairs!"

"My boy!" exclaimed Mr. Sapognikoff, jumping up from his chair and shaking the hand of the young mathematician. "If you can really do that, I will give you my daughter's hand and make you a junior partner in my business.

"But," he added after a short reflection, "Möbius or no Möbius, there will be no wedding until you return from the first Amazon trip with the load of converted shoes. I will, though, give you a preliminary partnership contract which you can study during your trip and which we'll sign as soon as you come back with the proof. My secretary will deliver to you that contract and an assortment of right-footed shoes at the airport. Good-by, and good luck!"

Stan walked out of Sapognikoff's office beaming, and full of hopes.

"It is not the heat, it is the humidity." The sentence was hammering into the young mathematician's head through the entire exhausting trip up the Amazon River.

Although the description of all the perils of that trip, first by a small steamboat, and then by foot through tropical jungles surrounding the vortex point, does not fall within the scope of the present article, one cannot leave unmentioned such important items as: alligators, heat, humidity, mosquitoes, more humidity, and more mosquitoes. Besides all that, Stan suffered badly from an allergy to some tropical plant which almost cost him his life. But, sick as he was,

he was leading the way, and a little caravan of a handful of Indian porters carrying shoe boxes was proceeding along the route which was supposed to bring them around the vortex point. Stan's head was swirling around because of the fever in his body, and later on he could never figure out whether the lopsided landscape, with some of the trees growing at most unusual angles, and certain sections of the forest hanging practically upside down, was his imagination or the actual fact. On the way back to the river he became delirious, and had to be carried by the porters. When he finally recovered consciousness, the boat was steaming smoothly down the river back to civilization, the weather was more tolerable, and numerous tropical birds were saturating the air with a gamut of shrill sounds. Rising to his feet, Stan walked to the stern of the boat where the shoe boxes were piled in disorder, and opened one of them marked: "Lady's Oxford. White. Size 6D, Right shoe." And, oh horror, it *was* the right shoe, and not the *left* one into which it was supposed to be turned! Apparently his theory was completely wrong, and all his efforts would never earn him Vera's hand!

Frantically he went on opening other boxes. There was a man's patent leather shoe, a lady's velvet shoe boot, a tiny pink baby shoe . . . But, they all were right-footed as they were when he inspected them before departure. In despair, he threw all overboard to the great delight of the alligators.

When Stan stepped out of the Pan American airliner, both Vera and her father were there to greet him.

"Where are the shoes?" asked Mr. Sapognikoff anxiously.

"I fed them to the alligators," answered Stan grimly. "I don't know what was wrong, but they all remained right-footed. I must have made some basic mistake in my calculations, and there isn't such a thing as a three-dimensional Möbius twist."

"Oh, no!" murmured Vera faintly.

"I am very sorry, Sir," continued Stan, "for causing you all this trouble with my fantastic theory. I think it would be only fair if I returned to you unsigned our partnership contract."

And, producing a rather battered document from the pocket of his traveling jacket, he handed it over to the old man.

"Very strange," said Mr. Sapognikoff, glancing at the document. "I cannot even read it."

"Mirror writing!" exclaimed Vera, looking at it, too. "It *is* mirror writing, so the things *did* change after all."

At a flash the explanation of his alleged failure, which wasn't a failure at all, dawned in Stan's head. Nothing was wrong, and every single right-footed shoe he carried with him turned into a left-footed one. But he also became left-footed and left-handed, and having changed himself into his mirror image, he naturally could not notice the same change in the shoes.

"Feel my heart," said Stan to Vera. "No, not here; my heart is now on the other side."

"I will love you just the same," smiled Vera happily.

"Too bad about the shoes," said Sapognikoff. "But I guess this document, and maybe an X-ray picture of your chest, can be considered as a definite proof. Thus, we will sign the partnership agreement as soon as this document is retyped in a proper way, if you practice writing your name again from left to right. And, of course, you and Vera may go ahead with your wedding plans."

But things were still not right. Ever since his return from Brazil, Stan's health was deteriorating and, although he ate healthy meals, he seemed to be suffering from malnutrition. A famous dietitian who was called in for consultation diagnosed his trouble as due to a complete inability to digest any protein food; in fact, the bacon and eggs he ate at breakfast and the most tasty dinner steaks were passing through

him as if they were made of sawdust. Having learned about Stan's adventure in South America, and after having checked the fact that his heart was really displaced to the opposite side of his chest, the dietitian came out with the complete explanation of the mysterious sickness.

"The trouble with you," he said, "is that your digestive enzymes, as well as all others, turned from *levo-* to *dextra-*variety, and are helpless in their task of assimilating any proteins in ordinary foodstuffs which all possess *levo-*symmetry."

"What do you mean by *levo-* and *dextra-*proteins?" asked Stan, who was never strong in chemistry.

"It is very simple," said the dietitian, "and very interesting, too. The proteins, which are the most important constituents of all living organisms, and an important part of any diet, are complex chemical substances composed of a large number of rather simple units known as amino acids. There are twenty different kinds of amino acids, and the way they are put together to form a protein molecule determines whether one gets gastric juice, muscle fiber, or the white of an egg. Each amino acid contains a so-called *amino-group*, an *acid group* and a *hydrogen atom*, attached to the main body of the molecule, known as *residue*, which determines its chemical and biological properties. Imagine that the palm of your hand represents the *residue* of some particular amino acid. Stick an *amino* group on your thumb, an *acid* group on your index finger, a *hydrogen* atom on your middle finger, and you will have a fairly good idea of how these basic units of all living matter look."

"Oh, I see now," said Stan. "One gets *levo*, and *dextra* varieties of these molecular models depending on whether one uses his left or right hand. Isn't that correct?"

"Quite correct. But, although chemically both molecules are identical, because of their opposite mirror symmetry, they act differently on polarized light, and can be distinguished by optical methods.

"Now the great mystery of nature is that, although in ordinary chemical synthesis carried out in a laboratory both levo- and dextra-varieties are produced in equal amounts, only levo-variety is used by living organisms. All the proteins, in me, in you, in a dog, in a fish, in an oak tree, in an amoeba, or in influenza virus, are built exclusively by the levo-variety of amino acids."

"But why?" asked Stan in surprise. "Does the levo-variety have any advantage from the biological point of view?"

"None whatsoever. In fact, one can imagine two coexisting organic worlds, levo and dextra, which may, or may not, have gone through the same process of organic evolution. The possibility is not excluded that such two organic worlds actually could have existed during the early history of our planet, and that, just by chance, the levo-organisms developed some improvement, giving them an advantage in the struggle for existence over the dextra ones who then became extinct."

"And you mean that after traveling around the Möbius vortex point, I belong now to this nonexisting dextra world?"

"Exactly so," said the dietitian, "and although you can get some benefit from such foodstuff as fats and starches the molecules of which do not possess mirror asymmetry, ordinary protein diet is out of the question for you at the moment. But, I am sure, your father-in-law will subsidize a special biochemical laboratory which will synthesize for you dextra-varieties of all common food proteins. In the meantime we can feed you on antibiotics—such as penicillin, for example."

"Antibiotics?" repeated Stan with surprise. "Why should antibiotics be good for me?"

"I forgot to tell you that there *are* a few living organisms, mostly molds, which use, at least partially, dextra amino acids in their bodies."

"You mean they are the survivals of this extinct dextra world?"

"Most probably not. It is more likely that these molds have developed the ability to synthesize, and to use, dextra amino acids as a defense against the bacteria which are their worst enemies. This defense is good against *all* kinds of bacteria, since all bacteria are levo-organisms and develop bad indigestion when fed on dextra food. But it will be good for you."

"Fine," said Stan, smiling. "Order me a large dish of penicillin *au gratin*. I am starved. And send Vera along to see me—I want to tell her the good news!"