feeling of falseness because of this I explain that a "radical" in Gallatin County, Montana, is a little different from a radical somewhere else.

"This was a college," I tell them, "where the wife of the president of the United States was actually banned because she was 'too controversial.' "

"Who?"

"Eleanor Roosevelt."

"Oh my God," John laughs, "that must have been *wild.*"

They want to hear more but it's hard to say anything. Then I remember one thing: "In a situation like that a *real* radical's actually got a perfect setup. He can do almost anything and get away with it because his opposition have already made asses out of themselves. They'll make him look good no matter what he says."

On the way out we pass a city park which I noticed last night, and which produced a memory concurrence. Just a vision of looking up into some trees. He had slept on that park bench one night on his way through to Bozeman. That's why I didn't recognize that forest yesterday. He'd come through at night, on his way to the college at Bozeman.

9

NOW WE FOLLOW THE YELLOWSTONE VALLEY RIGHT ACROSS Montana. It changes from Western sagebrush to Midwestern cornfields and back again, depending on whether it's under irrigation from the river. Sometimes we cross over bluffs that take us out of the irrigated area, but usually we stay close to the river. We pass by a marker saying something about Lewis and Clark. One of them came up this way on a side excursion from the Northwest Passage.

Nice sound. Fits the Chautauqua. We're really on a kind of Northwest Passage too. We pass through more fields and desert and the day wears on.

I want to pursue further now that same ghost that Phaedrus pursued—rationality itself, that dull, complex, classical ghost of underlying form.

This morning I talked about hierarchies of thought—the system. Now I want to talk about methods of finding one's way through these hierarchies—logic.

Two kinds of logic are used, inductive and deductive. Inductive inferences start with observations of the machine and arrive at general conclusions. For example, if the cycle goes over a bump and the engine misfires, and then goes over another bump and the engine misfires, and then goes over another bump and the engine misfires, and then goes over a long smooth stretch of road and there is no misfiring, and then goes over a fourth bump and the engine misfires again, one can logically conclude that the misfiring is caused by the bumps. That is induction: reasoning from particular experiences to general truths.

Deductive inferences do the reverse. They start with general knowledge and predict a specific observation. For example, if, from reading the hierarchy of facts about the machine, the mechanic knows the horn of the cycle is powered exclusively by electricity from the battery, then he can logically infer that if the battery is dead the horn will not work. That is deduction.

Solution of problems too complicated for common sense to solve is achieved by long strings of mixed inductive and deductive inferences that weave back and forth between the observed machine and the mental hierarchy of the machine found in the manuals. The correct program for this interweaving is formalized as scientific method.

Actually I've never seen a cycle-maintenance problem complex enough really to require full-scale formal scientific method. Repair problems are not that hard. When I think of formal scientific method an image sometimes comes to mind of an enormous juggernaut, a huge bulldozer—slow, tedious, lumbering, laborious, but invincible. It takes twice as long, five times as long, maybe a dozen times as long as informal mechanic's techniques, but you know in the end you're going to *get* it. There's no fault isolation problem in motorcycle maintenance that can stand up to it. When you've hit a really tough one, tried everything, racked your brain and nothing works, and you know that this time Nature has really decided to be difficult, you say, "Okay, Nature, that's the end of the *nice* guy," and you crank up the formal scientific method.

For this you keep a lab notebook. Everything gets written down, formally, so that you know at all times where you are, where you've been, where you're going and where you want to get. In scientific work and electronics technology this is necessary because otherwise the problems get so complex you get lost in them and confused and forget what you know and what you don't know and have to give up. In cycle maintenance things are not that involved, but when confusion starts it's a good idea to hold it down by making everything formal and exact. Sometimes just the act of writing down the problems straightens out your head as to what they really are.

The logical statements entered into the notebook are broken down into six categories: (1) statement of the problem, (2) hypotheses as to the cause of the problem, (3) experiments designed to test each hypothesis, (4) predicted results of the experiments, (5) observed results of the experiments and (6) conclusions from the results of the experiments. This is not different from the formal arrangement of many college and high-school lab notebooks but the purpose here is no longer just busywork. The purpose now is precise guidance of thoughts that will fail if they are not accurate.

The real purpose of scientific method is to make sure Nature hasn't misled you into thinking you know something you don't actually know. There's not a mechanic or scientist or technician alive who hasn't suffered from that one so much that he's not instinctively on guard. That's the main reason why so much scientific and mechanical information sounds so dull and so cautious. If you get careless or go romanticizing scientific information, giving it a flourish here and there, Nature will soon make a complete fool out of you. It does it often enough anyway even when you don't give it opportunities. One must be extremely careful and rigidly logical when dealing with Nature: one logical slip and an entire scientific edifice comes tumbling down. One false deduction about the machine and you can get hung up indefinitely.

In Part One of formal scientific method, which is the statement of the problem, the main skill is in stating absolutely no more than you are positive you know. It is much better to enter a statement "Solve Problem: Why doesn't cycle work?" which sounds dumb but is correct, than it is to enter a statement "Solve Problem: What is wrong with the electrical system?" when you don't absolutely *know* the trouble is *in* the electrical system. What you should state is "Solve Problem: What is wrong with cycle?" and *then* state as the first entry of Part Two: "Hypothesis Number One: The trouble is in the electrical system." You think of as many hypotheses as you can, then you design experiments to test them to see which are true and which are false.

This careful approach to the beginning questions keeps you from taking a major wrong turn which might cause you weeks of extra work or can even hang you up completely. Scientific questions often have a surface appearance of dumbness for this reason. They are asked in order to prevent dumb mistakes later on.

Part Three, that part of formal scientific method called experimentation, is sometimes thought of by romantics as all of science itself because that's the only part with much visual surface. They see lots of test tubes and bizarre equipment and people running around making discoveries. They do not see the experiment as part of a larger intellectual process and so they often confuse experiments with demonstrations, which look the same. A man conducting a gee-whiz science show with fifty thousand dollars' worth of Frankenstein equipment is not doing anything scientific if he knows beforehand what the results of his efforts are going to be. A motorcycle mechanic, on the other hand, who honks the horn to see if the battery works is informally conducting a true scientific experiment. He is testing a hypothesis by putting the question to nature. The TV scientist who mutters sadly, "The experiment is a failure; we have failed to achieve what we had hoped for," is suffering mainly from a bad scriptwriter. An experiment is never a failure solely because it fails to achieve predicted results. An experiment is a failure only when it also fails adequately to test the hypothesis in question, when the data it produces don't prove anything one way or another.

Skill at this point consists of using experiments that test only the hypothesis in question, nothing less, nothing more. If the horn honks, and the mechanic concludes that the whole electrical system is working, he is in deep trouble. He has reached an illogical conclusion. The honking horn only tells him that the battery and horn are working. To design an experiment properly he has to think very rigidly in terms of what directly causes what. This you know from the hierarchy. The horn doesn't make the cycle go. Neither does the battery, except in a very indirect way. The point at which the electrical system *directly* causes the engine to fire is at the spark plugs, and if you don't test here, at the output of the electrical system, you will never really know whether the failure is electrical or not.

To test properly the mechanic removes the plug and lays it against the engine so that the base around the plug is electrically grounded, kicks the starter lever and watches the sparkplug gap for a blue spark. If there isn't any he can conclude one of two things: (a) there is an electrical failure or (b) his experiment is sloppy. If he is experienced he will try it a few more times, checking connections, trying every way he can think of to get that plug to fire. Then, if he can't get it to fire, he finally concludes that *a* is correct, there's an electrical failure, and the experiment is over. He has proved that his hypothesis is correct.

In the final category, conclusions, skill comes in stating no more than the experiment has proved. It hasn't proved that when he fixes the electrical system the motorcycle will start. There may be other things wrong. But he does know that the motorcycle isn't going to run until the electrical system is working and he sets up the next formal question: "Solve problem: what is wrong with the electrical system?"

He then sets up hypotheses for these and tests them. By asking the right questions and choosing the right tests and drawing the right conclusions the mechanic works his way down the echelons of the motorcycle hierarchy until he has found the exact specific cause or causes of the engine failure, and then he changes them so that they no longer cause the failure.

An untrained observer will see only physical labor and often get the idea that physical labor is mainly what the mechanic does. Actually the physical labor is the smallest and easiest part of what the mechanic does. By far the greatest part of his work is careful observation and precise thinking. That is why mechanics sometimes seem so taciturn and withdrawn when performing tests. They don't like it when you talk to them because they are concentrating on mental images, hierarchies, and not really looking at you or the physical motorcycle at all. They are using the experiment as part of a program to expand their hierarchy of knowledge of the faulty motorcycle and compare it to the correct hierarchy in their mind. They are looking at underlying form.

A car with a trailer coming our way is passing and having trouble getting back into his lane. I flash my headlight to make sure he sees us. He sees us but he can't get back in. The shoulder is narrow and bumpy. It'll spill us if we take it. I'm braking, honking, flashing. Christ Almighty, he panics and heads for our shoulder! I hold steady to the edge of the road. Here he COMES! At the last moment he goes back and misses us by inches.

A cardboard carton flaps and rolls on the road ahead of us, and we watch it for a long time before we come to it. Fallen off somebody's truck evidently.

Now the shakes come. If we'd been in a car that would've been a head-on. Or a roll in the ditch.

We pull off into a little town that could be in the middle of Iowa. The corn is growing high all around and the smell of fertilizer is heavy in the air. We retreat from the parked cycles into an enormous, high-ceilinged old place. To go with the beer this time I order every kind of snack they've got, and we have a late lunch on peanuts, popcorn, pretzels, potato chips, dried anchovies, dried smoked fish of some other kind with a lot of fine little bones in it, Slim Jims, Long Johns, pepperoni, Fritos, Beer Nuts, ham-sausage spread, fried pork rind and some sesame crackers with an extra taste I'm unable to identify.

Sylvia says, "I'm still feeling weak."

She somehow thought that cardboard box was our motorcycle rolling over and over again on the highway.

10

OUTSIDE IN THE VALLEY AGAIN THE SKY IS STILL LIMITED BY THE bluffs on either side of the river, but they are closer together and closer to us than they were this morning. The valley is narrowing as we move toward the river's source.

We're also at a kind of beginning point in the things I'm discussing at which one can at last start to talk about Phaedrus' break from the mainstream of rational thought in pursuit of the ghost of rationality itself.

There was a passage he had read and repeated to himself so many times it survives intact. It begins:

> In the temple of science are many mansions . . . and various indeed are they that dwell therein and the motives that have led them there.
>
> Many take to science out of a joyful sense of superior intellectual power; science is their own special sport to which they look for vivid experience and the satisfaction of ambition; many others are to be found in the temple who have offered the products of their brains on this altar for purely utilitarian purposes. Were an angel of the Lord to come and drive all the people belonging to these two categories out of the temple, it would be noticeably emptier but there would still be some men of both present and past times left inside. . . . If the types we have just expelled were the only types there were, the temple would never have existed any more than one can have a wood consisting of nothing but creepers . . . those who have found favor with the angel . . . are somewhat odd, uncommunicative, solitary fellows, really less like each other than the hosts of the rejected.
>
> What has brought them to the temple . . . no single answer will cover . . . escape from everyday life, with its painful crudity and hopeless dreariness, from the fetters of one's own shifting desires. A finely tempered nature longs to escape from his noisy cramped surroundings into the silence of the high mountains where the eye ranges freely through the still pure air and fondly traces out the restful contours apparently built for eternity.

The passage is from a 1918 speech by a young German scientist named Albert Einstein.

Phaedrus had finished his first year of University science at the age of fifteen. His field was already biochemistry, and he intended to specialize at the interface between the organic and inorganic worlds now known as molecular biology. He didn't think of this as a career for his own personal advancement. He was very young and it was a kind of noble idealistic goal.

> The state of mind which enables a man to do work of this kind is akin to that of the religious worshipper or lover. The daily effort comes from no deliberate intention or program, but straight from the heart.

If Phaedrus had entered science for ambitious or utilitarian purposes it might never have occurred to him to ask questions about the nature of a scientific hypothesis as an entity in itself. But he did ask them, and was unsatisfied with the answers.

The formation of hypotheses is the most mysterious of all the categories of scientific method. Where they come from, no one knows. A person is sitting somewhere, minding his own business, and suddenly—flash!—he understands something he didn't understand before. Until it's tested the hypothesis isn't truth. For the tests aren't its source. Its source is somewhere else.